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Technical Report *September 1976*

MAXIMIZING PROTECTION IN NEW EOCs FROM NUCLEAR BLAST AND RELATED EFFECTS: GUIDANCE PROVIDED BY LECTURE AND CONSULTATION

Prepared for:

DEFENSE CIVIL PREPAREDNESS AGENCY
WASHINGTON, D.C. 20301

Contract No. DCPA01-76-C-0161
DCPA Work Unit 1154H

SRI Project 4620

STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The project was devoted to providing consultation and lecture guidance on applications of combined nuclear effects slanting techniques to new basements (all EOCs). The bulk of the report consists of several appendices that publish additional slanting guidance, found needed or useful while providing the consultation and lecture assistance. The new guidance has been so arranged that it may be added to the previously published guidance,[1-5] by using Appendices A and B herein.

Lecture Guidance/Assistance

Two special lecture courses were given for the purpose of familiarizing DCPA

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20 ABSTRACT (Continued)
Region Staff and RESG engineers - whose normal work is representing the U.S. Government's interests in the contract construction of EOCs under matching funds - with combined nuclear effects slanting (design modifications) of such EOCs, especially for air blast resistance; they were held at the DCPA Staff College, Battle Creek. The Project Leader, H. L. Murphy, was a consultant-lecturer backing up the course director, Thomas P. Carroll. Generally, Mr. Carroll introduced each subject area using the TR-20 Vol. 4 DRAFT as a basic source, and in a lecture following soon thereafter Mr. Murphy discussed the subject in terms of full slanting with reference made to pertinent portions of the 3-volume slanting guidance handout,[5] as well as to special lecture topics.

Complete notes on most of the special lecture topics are in Appendix A.

Consultation Guidance/Assistance

There were many informal discussions, mostly telephonic, with or through students from the above courses, which amounted to consultation on potential applications of full slanting to EOCs. There were a few field cases where a report was made to DCPA; selected correspondence is in Appendix C.

Findings/Conclusion

The following findings seem to have been demonstrated during the course of the project work in either lecturing or consultation assistance or both:

1. To minimize the cost of combined effects or full slanting especially the addition of blast resistance to the accepted fallout protection, design professionals must think along those lines from the very first stage, and must be educating the policymakers to do the same, with help from DCPA/RESG staff professional engineers and architects.

2. The value of the two special Protective Construction P.C. courses offered was clearly shown by subsequent events.

3. There is apparently a need for technical guidance on the engineered, as well as expedient, blast upgrading of existing structures.

4. If combined effects protection is to be moved forward, then more of the kind of simplification/predesign work represented herein and in References 5 and 6 and their like must be done.

It is wholly unreasonable to expect engineers whose work is supervising A&E and construction contracts, to be structural engineers and expert in handling dynamic loadings and other nuclear weapons effects. They should have specialized help available whenever needed. Costs are small and savings are potentially significant in amount and professional time.

1. Murphy, H. L., Feasibility Study of Slanting for Combined Nuclear Weapons Effects (Revised), Stanford Research Institute Technical Report, for U. S. Office of Civil Defense (now Defense Civil Preparedness Agency), 2 vols., July 1971 (AD-734 831 and 2)
2. Murphy, H. L., and J. E. Beck, Slanting for Combined Nuclear Weapons Effects: EXAMPLES WITH ESTIMATES, AND AIR BLAST ROOM FILLING, (ibid.), June 1973. (AD-783 061)
3. Murphy, H. L., and J. R. Rempel, Slanting for Combined Nuclear Weapons Effects: FIRE HAZARD REDUCTION, (ibid.), August 1972. (AD-763 472)
4. Murphy, H. L., and J. E. Beck, Slanting for Combined Nuclear Weapons Effects: BLAST-RESISTANT DESIGN/ANALYSIS WITH EXAMPLES, (ibid.), December 1974. (AD-A016 631)
5. Murphy, H. L., J. R. Rempel, and J. E. Beck, SLANTING IN NEW BASEMENTS FOR COMBINED NUCLEAR WEAPONS EFFECTS: A Consolidated Printing of Four Technical Reports, (ibid.), 3 vols., October 1975. (AD-A023 237) Reports used are References 1, 2, 3 and 4 above.
6. Murphy, H. L., C. K. Wiehle, and E. E. Pickering, Upgrading Basements for Combined Nuclear Weapons Effects: Expedient Options, (ibid.), May 1976. (AD-A030 762)

STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

Technical Report
Summary

September 1976

MAXIMIZING PROTECTION IN NEW EOCs FROM NUCLEAR BLAST AND RELATED EFFECTS: GUIDANCE PROVIDED BY LECTURE AND CONSULTATION

By: H. L. MURPHY, *Sr. Civil Engineer*
J. E. BECK, *Research Engineer*

Facilities and Housing Research

Prepared for:

DEFENSE CIVIL PREPAREDNESS AGENCY
WASHINGTON, D.C. 20301

Contract No. DCPA01-76-C-0161
DCPA Work Unit 1154H

SRI Project 4620

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DCPA Review Notice

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Emergency Operating Centers -- EOCs).

SUMMARY

This ~~The~~ project was devoted to providing consultation and lecture guidance on applications of combined nuclear effects slanting techniques to new basements (all ~~EOCs)~~. The bulk of the report consists of several appendices that publish additional slanting guidance, found needed or useful while providing the consultation and lecture assistance. The new guidance has been so arranged that it may be added to the previously published guidance.[1-5]*

Lecture Guidance/Assistance

Two special lecture courses were given ~~for the purpose of~~ to familiarize ~~ising~~ DCPA Region Staff and RESG engineers-- whose normal work is representing the U.S. Government's interests in the contract construction of EOCs ~~under matching funds~~ --with combined nuclear effects slanting (design modifications) of such EOCs, especially for air blast resistance. The first of two special Protective Construction courses was held at the DCPA Staff College 3-14 November 1975; a DRAFT revision of DCPA's TR-20 (Vol. 4) Nov. 1975 was given trial use with a class of eleven engineers, nine from RESGs, plus one each from DCPA headquarters and the Office of the Chief of Engineers, U. S. Army. A second course was held, April 26-May 7, 1976, with a class of ten engineers. In both courses, the Project Leader, H. L. Murphy, was a consultant-lecturer backing up the course director, Thomas P. Carroll. Generally, Mr. Carroll introduced each subject area using the TR-20 Vol. 4 DRAFT as a basic source, and in a lecture following soon thereafter Mr. Murphy discussed the subject in terms of full slanting with reference made to pertinent portions of the 3-volume slanting guidance handout, as well as to special lecture topics, the write-up of which constitute the body of this report.[5] Mr. Murphy led each course attendee through ~~the latter's~~ hands-on, personal use of time-sharing computer, stored programs on blast slanting design of a R/C one-way slab and a wood beam.

Complete notes on most of the special lecture topics are in Appendix A hereto. The notes are paginated for addition to Reference 81, but will only fit into the pagination if the continuity and correction pages of Appendix B hereto are also used.

Consultation Guidance/Assistance

There were many informal discussions, mostly telephonic of course, with or through students from the above-described courses, sometimes

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* Superscript numerals are related to REFERENCES listed at the end of this Summary.

jointly or separately with their supervisors or colleagues, which discussions amounted to consultation on potential application of full slanting to an EOC. There were a few field cases where a report was made to Mr. G. N. Sisson, DCPA headquarters, and they constitute all of the really significant cases. They were summarized in the last of the contract Quarterly Progress Reports and selected pertinent correspondence is included in Appendix C hereto.

Findings/Conclusion

The following findings seem to have been demonstrated during the course of the project work in either lecturing or consultation assistance or both:

1. To minimize the cost of combined effects or full slanting especially the addition of blast resistance to the accepted fallout protection, design professionals must think along those lines from the very first stage, and must be educating the policymakers to do the same. It is intended that DCPA staff professional engineers and architects, including such professionals available in RESGs, be given sufficient training (as they were in each of the two special Protective Construction (P.C.) courses described above) so that they can recognize an opportunity for full protection in a particular building situation, argue convincingly for consideration of combined effects protection, and know when to request some specialized consulting help to back them up.

2. The value of the two special P.C. courses offered was clearly shown by subsequent events wherein all of the EOCs known to have been brought up for the addition of blast slanting came from students at the two P.C. courses, directly or indirectly but mostly the former.

3. There is apparently a need for technical guidance on the engineered, as well as expedient, blast upgrading of existing structures, most particularly in the many existing EOCs. This is a tough technical nut to crack in R/C structures and worse in masonry structures. Research work is underway on this matter.

4. If combined effects protection is to be moved forward in numbers of EOCs or other buildings, either in terms of actual construction/conversion now, or preparation for future construction/conversion, then more of the kind of simplification/predesign work represented herein and in References 5 and 6 and their like must be done. A national reservoir of engineers trained for this kind of structural design simply does not exist, as it does with fallout shelter analysts.

One must reach the conclusion that it is wholly unreasonable to expect engineers, whose daily work is supervising A/E and construction contracts plus keeping abreast of technical matters, fund regulations and related administrivia, to also be not just competent structural engineers but expert in a very specialized field of structural engineering involving the handling of dynamic loadings and other technical

matters related to nuclear weapons effects on structures. In short, they can be expected, through training, to have some working familiarity with such special fields, but should have available to them some specialized help when and as needed. Costs are small and savings are potentially significant in amount. In a survey made by headquarters staff personnel, all Regional Directors supported the need for the specialized training and availability of specialized technical help. Similarly, several Regional Offices have reiterated their support of the need for on-call specialized technical help, as indicated by informal telephone conversations and in some cases in writing (Appendices C and D).

Acknowledgments

Through suggestions and guidance, the technical help of G. N. Sisson and M. A. Pachuta, U.S. Defense Civil Preparedness Agency, was freely given and is gratefully acknowledged.

Note

Every effort has been made to ensure the accuracy of all guidance and programs included herein. However, no warranty, expressed or implied, is made as to the recommended procedures or programs. The reader-user is expected to make the final evaluation as to the usefulness of all material contained herein. Recommendations made herein should not be substituted for the knowledge, experience, and judgment of the professional engineer or architect, but should be treated as guidance for consideration by the professional, regarding the best method of achieving specific design goals.

References

1. Murphy, H. L., Feasibility Study of Slanting for Combined Nuclear Weapons Effects (Revised), Stanford Research Institute Technical Report, for U.S. Office of Civil Defense (now Defense Civil Preparedness Agency), 2 vols., July 1971. (AD-734 831 and 2)

2. Murphy, H. L., and J. E. Beck, Slanting for Combined Nuclear Weapons Effects: EXAMPLES WITH ESTIMATES, AND AIR BLAST ROOM FILLING, Stanford Research Institute Technical Report, for Defense Civil Preparedness Agency, June 1973. (AD-783 061)

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4. Murphy, H. L., and J. E. Beck, Slanting for Combined Nuclear Weapons Effects: BLAST-RESISTANT DESIGN/ANALYSIS WITH EXAMPLES, Stanford Research Institute Technical Report, for Defense Civil Preparedness Agency, December 1974. (AD-A016 631)

5. Murphy, H. L., J. R. Rempel, and J. E. Beck, SLANTING IN NEW BASEMENTS FOR COMBINED NUCLEAR WEAPONS EFFECTS: A Consolidated Printing of Four Technical Reports, Stanford Research Institute Technical Reports, 3 vols., for U.S. Defense Civil Preparedness Agency, October 1975. (AD-A023 237) Reports used are References 1, 2, 3 and 4 above; omitted, of course, was any material in a later report that replaced material published in an earlier report.

6. Murphy, H. L., C. K. Wiehle, and E. E. Pickering, Upgrading Basements for Combined Nuclear Weapons Effects: Expedient Options, Stanford Research Institute Technical Report, for U.S. Defense Civil Preparedness Agency, May 1976. (AD-A030 762)

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Technical Report

September 1976

MAXIMIZING PROTECTION IN NEW EOCs FROM NUCLEAR BLAST AND RELATED EFFECTS: GUIDANCE PROVIDED BY LECTURE AND CONSULTATION

By: H. L. MURPHY, *Sr. Civil Engineer*
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Prepared for:

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CONTENTS

TABLES

FIGURES

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* Operation PLUMBBOB[90]

SUMMARY, FINDINGS AND CONCLUSIONS

Project Purpose and Scope

Because the project was devoted to providing consultation and lecture guidance on applications of combined nuclear effects slanting techniques to new basements (all EOCs), the body of this report is appropriately short; instead, the bulk of the report consists of several appendices that publish additional slanting guidance, found needed or useful during the providing of the consultation and lecture assistance. The new guidance has been so arranged that it may be added to the previously published guidance.[81*]

The project has been concisely described in Quarterly Progress Reports as follows:

"Briefly stated, this project calls for engineering consultation and lecturing services on the application of combined nuclear weapons effects or full slanting (i.e., building design modifications), especially for air blast, to . . . Emergency Operating Centers (EOCs) under design by architects/engineers (A&Es). Such services include: providing assistance directly, as well as through lecturing in two DCPA Staff College courses, in the training of professional personnel in the DCPA RESGs in full slanting, using written guidance developed in completed DCPA/SRI research projects; developing additional guidance as needed, but specifically including design procedures for two-way and flat slabs, numerical methods, and tabular or graphical solutions to both column and wall interaction equations; providing consultation assistance to A&Es designing EOCs, under coordination arrangements through the Contracting Officer's Technical Representative (COTR); and, collaborating with DCPA headquarters personnel in the preparation of material for professional training courses."

Lecture Guidance/Assistance

Two special lecture courses were given for the purpose of familiarizing DCPA Region Staff and RESG engineers - whose normal work is representing the U. S. Government's interest in the contract construction of

* Superscript numerals are related to listings in the REFERENCES section at the end of Appendix A.

EOCs under matching funds - with combined nuclear effects slanting (design modifications) of such EOCs, especially for air blast resistance. The two courses were described in a recent Quarterly Progress Report as follows:

"At a special Protective Construction course, held at the DCPA Staff College 3-14 November 1975, a DRAFT revision of DCPA's TR-20 (Vol. 4) Nov. 1975 was given trial use with a class of eleven engineers, nine from RESGs (representing all DCPA Regions except 8, with three from Reg. 4), plus one each from DCPA headquarters and the Office of the Chief of Engineers, U. S. Army. A second such course was held, April 26-May 7, 1976, with a class of ten engineers (Chief of EngServsDiv, Region 3; RESG engineers from Regions 1, 2(2), 4(2), and 6(2); and 2 USAF Reserve LCOLs on MOBDES ACDUTRA from Regions 7 and 8). In both courses, the Project Leader, H. L. Murphy, was a consultant-lecturer backing up the course director, Thomas P. Carroll of Carroll Associates, Bethesda, Maryland, also under DCPA contract. Generally, Mr. Carroll introduced each subject area using the TR-20 Vol. 4 DRAFT as a basic source, and in a lecture following soon thereafter Mr. Murphy discussed the subject in terms of full slanting with reference made to pertinent portions of the 3-volume slanting guidance handout.[81] Mr. Murphy led each course attendee through the latter's hands-on, personal use of time-sharing computer, stored programs on blast slanting design of a R/C one-way slab and a wood beam. The design programs were stored with the computer service ahead of time and are those included in the 3-volume full slanting guidance handout; the portable terminal was taken to Battle Creek by Mr. Murphy. (Few of the attendees admitted to having had previous experience in using time-sharing computer services/programs; in the first course only one attendee stated that he had any structural engineering design experience, which called for some rapid replanning of the course lectures; in the second course, career experience levels in structural engineering were similarly low.) Mr. Murphy also gave lectures on selected special topics: two had as an attachment a transmittal letter, copies of the two sets of lecture notes, and the distribution list of 11 students plus two "faculty" to whom the notes were furnished; five other special topics were included in his lectures, covered by written handouts prepared prior to the second course, and all later distributed to attendees at the first course with one revision sent to those in the second course. . . . Finally, his lectures also included such topics as expedient[82] and engineered upgrading of existing normal structures to improve their blast resistance, with an invitation for fonecalls/informal correspondence on upgrading needs; handling target analysis probabilities, with handout;[83] computer programming/coding/flow-charting, with handout; room-filling, including jets and a film thereon; and, sequential slides of two houses being broken up in nuclear field tests (Operation Cue), one each wood-frame ranch and two-story brick."

Complete notes on most of the above-mentioned topics are in Appendix A hereto. The notes are paginated for addition to Reference 81, but will only fit into the pagination if the continuity and correction pages of Appendix B hereto are also used.

Consultation Guidance/Assistance

There were many informal discussions, mostly telephonic of course, with or through students from the above-described courses, sometimes jointly or separately with their supervisors or colleagues, which discussions amounted to consultation on potential application of full slanting to an EOC. There were a few field cases where a report was made to Mr. G. N. Sisson, as required by the project contract, and they constitute all of the really significant cases. They were summarized as follows in the last of the contract Quarterly Progress Reports:

"Specific clearances, then a general approach, have been previously arranged with both the COTR and his Staff Director on contacting the various DCPA Regional offices to learn of planned EOCs that include basements in new construction, as candidates for reserach study and consulting support in work under this project of applying combined effects or full slanting to new EOCs. Actual field visits were each covered by prior oral approval of the COTR. Experience clearly showed that all planned EOCs brought up as slanting candidates were through the efforts of engineers who attended either of the two special Protective Construction Courses described above. Developments to date* on this project work are as follows:

"Region 7: As reported earlier, contact was made (through an attendee at the November 1975 P.C. Course) about a new EOC, then at the stage of concluding the preliminary planning and approvals phase, for the City of Alameda, California. It developed that it was too late to consider incorporating full slanting in this structure. Copies of reports and of the closing letter from the Regional Director, DCPA Region 7, were attached to the Quarterly Progress Report of April 16, 1976.†

"Region 6: As reported earlier, contact was made first with an engineer suggested by Mr. Sisson; the engineer in turn arranged for a fonecon discussion with the Director of Technical Services, Mr. Lyle Hebb. The latter fonecon developed that: The A&E for two existing EOCs (Kansas State and Grand Forks) had managed to include some blast slanting at no

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* August 13, 1976.

† Pertinent copies are included in Appendix C hereto.

additional cost through use of some innovative ideas. Region 6 has several instances, however, where they need engineered upgrading of existing EOCs, mostly in basements, but they had no new EOC candidates for use under this project.

"Region 5: First discussion of applying full slanting to a planned underground addition to the existing State of Texas EOC at Austin was between Mr. Sisson and Mr. Ray Burke, Director, Engineering Services, Region 5, following which Mr. Burke called the Project Leader for this project (12/17/75). Developments, slow at first, but getting into the project submittal stage from (state) Disaster Emergency Services (Texas DES) to their Department of Public Works, culminated in a meeting on 12 April 1976 of the Project Leader with DCPA Region 5 personnel (Messrs. Burke and Chas. V. Dansby of their RESG) in the forenoon (while enroute by government auto from Dallas to Austin) and of both with Mr. Frank T. Cox, Deputy State Coordinator, Texas DES, in the afternoon. Developments on this project caused preparation of the paper that became a handout at the second P.C. course mentioned above; the paper is one of those attached hereto, . . . (Arch and Conduit Structures - Corrugated-Steel and Reinforced Concrete)* . . . The meeting with Mr. Cox covered both rectilinear and the arch/conduit structures, but the latter seemed to offer the most interest for those present toward meeting the Texas State EOC expansion need.

"Region 4: First discussion of consulting assistance came on 4/27/76 from Mr. Bruce R. Newhard (RESG, Region 4), a student in the first P.C. course, the call coming while the second P.C. course was going on. The subject was expansion (approximately 10,000 sf) of the existing, blast-resistant EOC for Stark County, Ohio, located in Canton. Again the above-mentioned arch/conduit structures paper evinced considerable interest, at a meeting where architectural, structural, mechanical and electrical professional disciplines were represented. Copies of correspondence† attached hereto fully describe the meeting at Canton on June 18, 1976, and the follow-up supply of documents and information. Again, the meeting was held at the right time - during the early thinking stage wherein all persons concerned are open to fresh and alternative approaches.

"Further contact work was planned but project funds were too limited for further field trips. There is a very real need for specialist back-up to be continually available to the Regional Offices, including RESGs."

More recent information, based on admittedly preliminary estimates, indicates that the corrugated-steel arch/conduit underground structures

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* Included in Appendix A hereto, and prepared at the suggestion of Mr. G. N. Sisson of DCPA Headquarters.

† Pertinent copies are included in Appendix C hereto.

will cost less (offering inherent 50 to 60 psi blast overpressure protection, based on field tests) than rectilinear structures (designed for 15 to 30 psi).

Findings/Conclusion

The following findings seem to have been demonstrated during the course of the project work in either lecturing or consultation assistance or both:

1. To minimize the cost of combined effects or full slanting, especially the addition of blast resistance to the accepted fallout protection, design professionals must think along those lines from the very first stage, and must be educating the policymakers to do the same. Almost without exception, DCPA professional engineers and architects, including such professionals available in RESGs, are performing engineering administration functions, such as managing design and construction contracts, and have difficulty finding time to keep abreast of normal-use building design practices, if they can do so at all (e.g., ultimate strength versus working stress design in R/C is a glaring example). This is no indictment of these professionals - they are simply not working in engineering design, but in construction or other technical administration requiring application of engineering knowledge. To further expect these professionals to know and be able to apply engineering design techniques for special, time-varying loads on structures to be stressed far beyond their rebound/re-use strength (i.e., a "one-shot" performance) is unreasonable. What can be expected is that a substantial number of the engineers handling design/construction contracts for shelter can be given sufficient training (as they were in each of the two special Protective Construction (P.C.) courses described above) so that they can recognize an opportunity for full protection in a particular building situation, argue convincingly for consideration of combined effects protection, and know when to request some specialized consulting help to back them up. [It is understood that engineers competent in structural engineering design work are simply unavailable for hiring in the job levels and classifications being offered by DCPA Regional Offices and RESGs.]

2. The value of the two special P. C. courses offered was clearly shown by subsequent events wherein all of the EOCs known to have been brought up for the addition of blast slanting came from students at the two P. C. courses, directly or indirectly but mostly the former.

3. There is apparently a need for technical guidance on the engineered, as well as expedient, blast upgrading of existing structures, most particularly in the many existing EOCs. This is a tough technical nut to crack in R/C structures and worse in masonry structures. Nonetheless, research work is underway on this matter, now in a second phase at SRI and elsewhere. It is not at all difficult to perceive that no magic wand answers will be found; instead they may be costly, difficult to apply and/or inconvenient in use (such as in reduced clear space or spans).

4. If combined effects protection is to be moved forward in numbers of EOCs or other buildings, either in terms of actual construction/conversion now, or preparation for future construction/conversion, then more of the kind of simplification/predesign work represented herein and in References 81 and 82 and their like must be done. A national reservoir of engineers trained for this kind of structural design simply does not exist; in this connection, one should recall the tremendous effort put into training fallout shelter analysts, which is a very simple field of technical work by comparison to blast-resistant design of structures.

One must reach the conclusion that it is wholly unreasonable to expect engineers, whose daily work is supervising A/E and construction contracts plus keeping abreast of technical matters, fund regulations and related administrivia, to also be not just competent structural engineers but expert in a very specialized field of structural engineering involving the handling of dynamic loadings and other technical matters related to nuclear weapons effects on structures. In short, they can be expected, through training, to have some working familiarity with such special fields, but should have available to them some specialized help when and as needed. Costs are small and savings, if strengthened EOCs are a serious matter, are potentially significant in amount. In a survey made by headquarters staff personnel prior to the award of the contract

for which this is the final report, all Regional Directors supported the need for the specialized training and availability of specialized technical help, as described above. Similarly, several Regional Offices have reiterated their support of the need for on-call specialized technical help, as indicated by informal telephone conversations and in some cases in writing (Appendices C and D).

Acknowledgments

Through suggestions and guidance, the technical help of G. N. Sisson and M. A. Pachuta, U.S. Defense Civil Preparedness Agency, was freely given and is gratefully acknowledged.

Note

Every effort has been made to ensure the accuracy of all guidance and programs included herein. However, no warranty, expressed or implied, is made as to the recommended procedures or programs. The reader-user is expected to make the final evaluation as to the usefulness of all material contained herein. Recommendations made herein should not be substituted for the knowledge, experience, and judgment of the professional engineer or architect, but should be treated as guidance for consideration by the professional, regarding the best method of achieving specific design goals.

Appendix A

ADDITIONAL TYPICAL DESIGNS AND MISCELLANEOUS DESIGN TECHNIQUES

for incorporation into current combined effects

or full slanting guidance of Reference 81.

COST ESTIMATING FOR COMBINED EFFECTS SLANTING

1 Form of the Estimate

a. Work Items, Reference Plans and Detail Sketches

The first document of importance is not really a form, but is the brief description of the various jobs included in one work item. This work item list shows which work is included in a particular estimate and forms the basis for cost summaries. There is no particular format required, but it should be much simpler than the itemized estimates.

The reference plans are the drawings that locate and show the extent of the work required in the slanting effort. These plans may be as simple as marked-up copies of the architect's initial schematic drawings or as detailed as the architect's and engineer's contract drawings for an alternative bid. Their principal value is to show everybody involved the basis of the quantities used for the cost estimates and to provide a visual check list of the modifications to assure completeness of the slanting design. In Chapter 8 of the basic reference[81] are floor plans (for example Fig. 8-2 and Fig. 8-2A) comparing the original design (8-2) with the slanted design (8-2A). The work items are indicated by Key numbers.

The detail sketches are prepared to define the modified design of selected items as necessary to meet the blast effects or post-blast operational requirements. These are both the engineers' design statement and the definition of the construction work involved. Typical of these detail sketches are those for the various blast door details as shown[81] in Figure 8-OE.

b. Take-Off Sheets

When an item of the slanting work has been identified and designed, then a materials and labor Take-Off Sheet is prepared, which records the dimensions, weights, count and calculation of quantity for each assembly, so that the estimate can be reviewed and verified. An example of the Take-Off Sheet is shown as Figure 6-1A.1

c. Estimating Form

The estimating form is the working paper for all slanting estimates. On it is recorded each cost item, its unit of measure, unit prices, labor cost, material cost, cost of equipment, and mark-ups for overhead profit and taxes. It is important that this be a standard form used througout the estimate. An example is shown in Figure 6-1A.2

QUANTITY TAKE-OFF

Page ___ of ______

Building ______________________________ Date ______________

Division of Work ______________________________ By ______________

Ref.	DESCRIPTION		No. of UNITS	DIMENSIONS			QUANTITIES			

FIGURE 6-1A.1 TAKE-OFF FORM

PUBLIC WORKS SYSTEMS - STANFORD RESEARCH INSTITUTE - MENLO PARK, CALIFORNIA

PROJ. ____ DATE ____ EST. NO. ____

CONSTRUCTION ESTIMATE				DISTRIBUTION OF ITEMIZED PRICES							
				LABOR		MATERIAL		EQUIPMENT OR SUB-CONTRACTS		TOTAL	
ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											

APPROVED: ____ CHECKED: ____ PRICED: ____

FIGURE 6-1A.2 ESTIMATING FORM

2 Procedures

a. Incremental Costs

Most of the cost estimating of slanting can be done by calculating the amount to be added to the original cost estimate. The costs for the additional quantity of work may simply be the addition of a few inches more of concrete, more steel per cubic foot, more expense for solid core doors instead of normal hollow core doors, etc. An example of this process is taken from the Building 3 Slanting estimate. Most of the slanting computations will be done for a particular work item or group of tasks that go together by the very nature of the work, such as everthing involved in thickening a floor slab or that goes together as a convenient grouping of like items, such as all blast doors. See Figures 6-1A.3 and 6-1A.4

b. Complete Item Cost Estimates

It is sometimes necessary to make complete cost estimates for one item of work, as originally designed and then as designed for slanting. This is necessary when significant changes in column spacing are made, as in Building 4 (Ref.81). This results in wholesale differences in the calculations of formwork, shoring, concrete, rebars, stripping and finishing. The net differences may prove to be minor, but this cannot be known for sure until the two estimates are compared. The comparative estimate is also appropriate when the slanting work involves a variety of reductions in the originally designed work. In some cases it may be possible to use a prior estimate of the original design for the comparison, but only when it is known that the quantity take-offs and unit prices are for comparable work. See Figure 6-1A.5.

c. Summation and Mark-Up Calculations

In any of the work items there will be a variety of line items that are all set by the same dimension. For example, if the dimensions of a tee-slab are changed, it will affect concrete yardage, forming, stripping and finishing. It may also be concurrent with changes in steel reinforcement. All of these related items should be carried as a package or work-item. Each different cost or line item should be calculated, then they should all be added together and the contractor's mark-ups added at the appropriate rates for labor burden, sales taxes, and any carrying charges on materials and additional charges on equipment rentals. Next the increment of cost for the office overhead and profit is added and after that the rate for the completion bond. These mark-ups have been found to cause significant differences in the final cost estimates of the slanting effort when compared with early estimates of construction costs. However, to underestimate the cost of slanting is apt to cause much difficulty before the project is closed out.

QUANTITY TAKE-OFF

Page ___ of ___

Building 3A Date ______

Division of Work 1c Interior Support Walls, Columns, Footings By ______

Ref.	DESCRIPTION		No. of UNITS	DIMENSIONS			QUANTITIES			
	FOOTINGS-COL 5TG-5TM									
	EXCAVATE		2	31.0	2.5	1.0	155cf ÷ 27			5.74cy
	Concrete						FORM	Place	Finish	Cure
		Footings	2	31.0	2.66	1.0	124	165	165	165
		Ends	2	5.			10			
							134			
		Key	2	31.0			62 L.F.			
		Sandblast	2	31.0	1.0		62 S.F.			
	WALLS - COL 5TG to 5TM						FORM	Place	Finish	Cure
		8" wall	2	31.0	0.67	14.50	1798	602	1798	1798
								=22.3CY		
	REINFORCING									
	Footings		2	31.0	2.66	2.40				396 lbs
	Walls		2	31.0	1.32	14.50				1187
										1583 lbs

FIGURE 6-1A.3 TAKE-OFF EXAMPLE

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PUBLIC WORKS SYSTEMS - STANFORD RESEARCH INSTITUTE - MENLO PARK, CALIFORNIA

PROJECT Bldg 3A DATE ______ SHEET NO ______

1c Interior Support Walls, Columns, Footings

ITEM NO.	CONSTRUCTION ESTIMATE: DESCRIPTION	QUANTITY	UNIT	LABOR: UNIT PRICE	LABOR: AMOUNT	MATERIAL: UNIT PRICE	MATERIAL: AMOUNT	EQUIPMENT OR SUB-CONTRACTS: UNIT PRICE	EQUIPMENT OR SUB-CONTRACTS: AMOUNT	TOTAL: UNIT PRICE	TOTAL: AMOUNT
1	Div. 1 General Requirements	6	%								290
2											
3	Div. 2. Site Work										
4	Footings -										
5	Machine Excavation	6	cy	1.00	6		–	2.50	15	3.50	21
6	Trim Trench Bottom	155	sf.	0.15	23		–		–	0.15	15
7											
8	Div. 3 Concrete										
9	Footings - Form	134	s.f.	0.65	87	0.30	40	–	–	0.95	127
10	Place Conc.	6.11	c.y.	3.50	21	18.00	110	1.00	6	22.50	137
11	Finish	165	s.f.	0.03	5	–	–	–	–	0.03	5
12	Cure	165	s.f.	0.005	1	0.005	1	–	–	0.01	2
13	Key	62	l.f.	0.50	31	0.20	12	–	–	0.70	43
14	Sandblast	62	l.f.	0.15	9	0.15	9	–	–	0.30	18
15	Reinforcing Steel	396	lbs	–	–	–	–	0.15	59	0.15	59
16											
17	Wall - Form	1798	s.f.	0.90	1618	0.32	575	–	–	1.22	2193
18	Place Conc	22.3	c.y.	3.50	78	18.00	401	2.50	56	24.00	535
19	Finish - paint, patch	1798	s.f.	0.07	126	0.01	18	–	–	0.08	144
20	- sack	1798	s.f.	0.20	360	0.04	72	–	–	0.24	432
21	Cure	1798	s.f.	0.005	9	0.005	9	–	–	0.01	18
22	Reinforcing Steel	1187	lbs.	–	–	–	–	0.15	178	0.15	178
23											
24	Labor Burden	35	%		831		–		–		831
25	Sales Tax	5	%		–		62		–		62
26	Sub-Totals				3205		1309		604		5118
27	Contractors Mark-up	6	%						36		36
28	Bond	1/2	%						3		3
29					3205		1309		643		5157
30	Total										
31											

APPROVED: CHECKED: PRICED:

FIGURE 6-1A.4 INCREMENTAL ESTIMATE

PUBLIC WORKS SYSTEMS - STANFORD R[illegible]EARCH INSTITUTE - MENLO PARK, CALIFORNIA

PROJECT BLDG 4A
Summary

DATE

SHEET NO.

ITEM NO.	CONSTRUCTION ESTIMATE DESCRIPTION	QUANTITY	UNIT	LABOR UNIT PRICE	LABOR AMOUNT	MATERIAL UNIT PRICE	MATERIAL AMOUNT	EQUIPMENT OR SUB-CONTRACTS UNIT PRICE	EQUIPMENT OR SUB-CONTRACTS AMOUNT	TOTAL UNIT PRICE	TOTAL AMOUNT
1	1A Change CB Walls to Conc.				5468		3892		<666>		8695
2	Harden Existing Conc Walls				1266		3593		599		5458
3	Footing at C.B. Walls				1227		1308		190		2725
4											16878
5											
6	1B Harden Ramps				81		1149		5037		6267
7											
8	1C Wall at South Ramp				6424		1613		4084		12121
9	Total Item 1										$ 35266
10											
11	2 Columns and Col. Footings				47932		62162		87563		$ 197657
12											
13	3A Ground Floor Slab & Beams										
14	Existing				- 51628		- 46443		- 17382		- 215453
15	Revised				97427		106058		215938		419423
16											203970
17											
18	3B First Sublevel Slab & Beams										
19	Existing				- 50706		- 46388		- 110794		- 207888
20	Revised				62122		57204		141158		260484
21											$ 52596
22											
23	Total Item 3										256566
24											
25	4 New Storage Rooms				61		638		2097		$ 2796
26											
27											
28											
29											
30											
31	Subtotal - Carry Fwd										$ 492285

APPROVED:

CHECKED:

PRICED:

FIGURE 6-1A.5 COMPARATIVE ESTIMATE

The pattern of mark-ups is generally similar to the following, although it will vary for different contractors:

	Labor	Material	Subcontract	Total
Subtotals	L_1	M_1	S_1	T_1
Labor Burden	+35%			
Sales Tax		+5%		
Subcontractor's Mark-up			Included	
Subtotals	L_2	M_2	S_2	T_2
Contractor's OH Profit	+10%	+10%	+10%	+10%
Contractor's Total	L_3	M_3	S_3	T_3
Bond				+½%
Contract Price				T_4

The summary is similar to the various tables in the basic reference,[81] such as Table 8.3A and Table 8.0A. The first table is a comparative summary for Bldg. 3 at different overpressures. The second is the combined report on 8 cases at the 15 psi overpressure. This latter one would, for any one project, be an effective summary for presenting the slanting study estimates.

d. Sources of Estimating Data

There is a large number of publications that can be of assistance in preparing estimates. First, there are the estimating handbooks that describe in considerable detail the several steps of every building operation and the accompanying cost factors. The detail presented is probably much more than needed for slanting estimates. However, as a reference to be sure all major items of cost are included they can be helpful. The best known of these is Walker,[84] now in its 15th edition.

The second type of publication is the annual volume of average unit prices. The best of this type provides in-place costs for labor and material on some national average (of 20 selected cities, for example) for each of the important variables involved in a work item. In addition, index values of comparative cost are reported for a list of major cities, often by major labor categories. These comparative indices can be very important if the absolute cost is an important factor. Although the estimate may only be comparing the slanting cost with the original design -

which may or may not be priced - the total of slanting costs is usually the information of most importance. Care must be taken that the cost data are for the appropriate type of construction. A distinction is usually made between residential, and light commercial and industrial building costs on one hand, and data for major office buildings on the other hand. This is usually stated in the publication's Introduction. Another useful set of data is the comparative index for construction costs for past years. It is frequently necessary to review an estimate made 3 to 5 years ago and update it for a building project that has been set aside but is now being reconsidered.

Some of the generally accepted annual publications include Means,[85] National,[86] Richardson,[87] and Dodge.[88] Means offers an added feature in its twelve-page list of the range of probable costs per square foot by building type and by major subdivisions of the work in that building type; these data can be useful as a check, on a broad basis, of the total project. National separates the data for residential construction from that for commercial and industrial. The Richardson 3-volume set provides excellent detail and specific cost of a variety of work and material for the same functional item; in general, this may be too detailed for the preparation of slanting estimates. The Dodge data are based on the largest data system in the construction industry, maintained by McGraw-Hill, publishers of Engineering News-Record and Architectural Record, as well as local building industry daily publications; the data are simply presented, using the system of U.S. average prices with local modifiers for each major trade.

e. Use of Computer Services

In most slanting projects there is not enough data being processed in any one area to make it worthwhile to set up a new computer program, even on a low cost time-sharing computer service. However, the use of computers for construction estimates is becoming so well accepted that the architect or the developer of the property may already have an estimate program set up. In that case it would be most useful in estimating slanting costs. The one proviso would be that calculations used can be examined to verify the quantities, rates, unit prices and mark-ups.

A recent addition to the library of building cost volumes is the computerized estimating service, which provides estimates that use the data available in handbook form, but does the calculation and aggregation of costs by computer. This feature is offered with the Dodge manuals, for instance. This approach would be useful on total project cost estimates, but not on a series of work items with incremental costs.

Rebar Laps and Splices. If the ultimate or absolutely last bit of blast protection potential (i.e., beyond the design overpressure) is to be gained from R/C members, especially the cover slab over a basement shelter, all longitudinal rebars (top and bottom) should be capable of finally acting in tension. This anticipates that behavior just short of or at collapse will be either in a tensile membrane mode (like a suspension bridge) or yield line mode (along lines of highest moment, and forming teepees or lean-tos, around columns or along beams, respectively). (See the first footnote of page 6-41.)[81]

All R/C beam/slab design procedures herein use both top and bottom steel layers, tied together by vertical stirrups. The stirrups serve the usual shear/diagonal tension purposes, as well as to keep the top steel from buckling and breaking out when acting in compression during large downward deflections.

For beams/slabs at a simply supported end(s), the preferred approach would be to simply extend all top and bottom steel into the support(s). If this is too expensive for acceptance, however, the alternative would be to splice to a reduced bar size (preferably not more than one bar "number," or only one "number" at a time if multiple reductions are considered necessary) at a point(s) compatible with the applied moment diagram. The end reduced bars should still be extended into the exterior supports.

For beams/slabs at a continuous end(s) extending over a support(s), either approach just described for simply supported ends could be used, of course. However, there would be a strong economic impetus for bending up positive moment bottom bars to become negative moment top bars over the support(s). Should it be necessary to adopt the bentup bars approach, it is recommended that a shallow angle of bend be used (preferably say 20^o-30^o, but with 45^o as a limit), thereby reducing the larger elongations that could happen as angles of bend are made steeper, and facilitating action in or near the collapse modes described above.

It follows from the foregoing that, if all longitudinal rebars are to finally act in tension and at or near their ultimate strength, simple laps

cannot be used because by then all concrete will be badly cracked, thus all such rebars should be so connected that the full ultimate strength can be developed in as many bars as possible, certainly in the smallest bar of each connected line of reinforcing steel. It might be well to recall that, for example, A615-60 rebars, used in design procedures herein at 72 ksi, have shown ultimate strengths greater than 100 ksi in large bars under slow loadings,[89] and the 100 ksi could become much larger under blast loadings with their rapid strain rates. Thus, design that also considers the absolute ultimate level of protection potential (in terms of bare survival of even some of the shelterees), which a basement shelter might afford, could have a considerable payoff should a nuclear attack occur and should the shelter be subjected to an overpressure exceeding that selected for design.

Welding is expensive and difficult to inspect and control, generally; this is especially true when the goal is to develop the full ultimate strength of connected rebars. This goal removes butt welding from serious consideration, leaving welding of laps as the alternative that could ensure connections capable of meeting the goal. Unfortunately, adequate space for such welded laps may be unavailable or at least very difficult to provide in design.

Mechanical connectors are available that can furnish rebar butt splices through mechanical means, not a weldment. The splices can provide a joint with basically the same mechanical properties as those of, and with the same ultimate tensile strength as, an unspliced bar. One line of such mechanical connectors, known to the author through professional contacts,[31] technical literature,[89] and vendor catalogs, is manufactured by Erico Products, Inc., 34600 Solon Road, Cleveland, Ohio 44139.[89]* Installation of these connectors requires no welding knowledge

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* Their "mechanical connector is a reinforcing bar splice with a splice sleeve consisting of a thick-walled steel tube with deformations machined on the inner surface. The bars to be spliced are inserted into the sleeve and the space between the bars and sleeve is filled with molten iron produced by an exothermic chemical reaction in an external crucible. The solidified iron transfers the force through the splice by bond. The sleeve wall thickness and length are selected to develop the desired force in the spliced bars."[89]

or skill, only a brief instruction period; after installation, they can be visually inspected, adequately and without use of radiography. They can be installed in vertical, horizontal or sloping connections. Other lines of mechanical connectors are understood to be on the market. Space can also be a problem with mechanical connectors but less so than for welded laps. Space can be a lesser problem if the mechanical connectors are staggered, and such action will reduce deflections and cracking concentrations.[89]

Alternate Final Design Procedure.* This procedure is no more elaborate - in fact, it is closely like - the two preliminary design procedures,† yet is equal in precision to the above final design procedure.[81] The distinction among the four procedures is that this one* is limited to design parameters emcompassed by Table 6.6A; the others are not so limited. Table 6.6A will handle only values of f_{dy} = 52 or 72 ksi, and f'_c = 3, 4 or 5 ksi. It will also handle specific values of γ = 0.45, 0.6, 0.75 and 0.9. For other γ values, use of the nearest one should be adequate; if not, two designs may be developed using γ values above and below the desired value, then an interpolated design may be used.

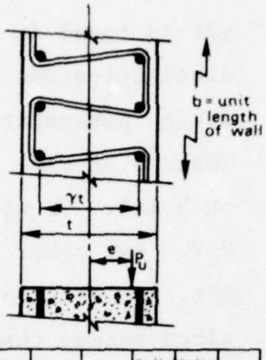
The program was tested by calculating many spot values for comparison with values in existing interaction tables prepared by ACI[67] and CRSI[69]; comparison results were excellent.

Shown below are both the steps of the design procedure and an example problem, the same (simply supported) interior wall design problem used in the final and preliminary design procedure examples.†

1. Given values for f'_c and f'_{dc}(ksi); f_{dy} (ksi); p_{so}(psi); t_o(sec); L(in.); p=p'; b(in.); μ; W(mt).‡	3;3.75;52; 15;1.55;144;.01;1;1;1
2. Obtain t_{oo}(sec) from approximate equations or graph of Fig. 3-7 (Fig. 3-6 for definition) Ref. 2.[81]	0.71
3. Calculate first trial using no vertical load. Assume value for T(sec); calculate t_{oo}/T.	0.04; 17.8
4. Using Figure 6-1, page 11-5 (with $t_d/T = t_{oo}/T$ and $x_m/x_y = \mu$),[81] read p_m/q (=p_m/q_y; for interpolation and reading of x_m/x_y = 1 line in Figure, p_m/q_y = 0.5 for $t_d/T \geq 7.0$); calculate q, using $p_m = p_{so}$.	0.50 30

* For only symmetrically reinforced walls (thus p'=p), due to limitations of Table 6.6A.
† Appendix G - Supplement.[81]
‡ See above Final Design Procedure, from opening through Step 1, for basic guidance on wall design and selection of p.[81]

Table 6.6A.1 Values of ultimate axial stress, P_u/A_g, for rectangular column with symmetric reinforcing steel, $f'_c = 3$ ksi, $f_{dy} = 52$ ksi, $\gamma = 0.45, 0.60, 0.75, 0.90$



p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .45 — VALUES OF ECCENTRICITY RATIO 6e/t																		Eff. t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	3.38	3.10	2.99	2.88	2.77	2.67	2.56	2.31	2.07	1.87	1.69	1.39	1.09	0.67	0.48	0.18	0.11	0.07	1.00	65.2	49.2	2.21	1.32	0.22
.012	3.47	3.18	3.07	2.95	2.84	2.73	2.62	2.37	2.13	1.92	1.74	1.43	1.17	0.74	0.52	0.21	0.13	0.07	1.00	68.2	56.3	2.26	1.31	0.24
.014	3.55	3.25	3.14	3.02	2.90	2.79	2.68	2.42	2.18	1.98	1.78	1.49	1.23	0.80	0.58	0.23	0.14	0.08	1.00	71.3	63.0	2.31	1.31	0.27
.016	3.64	3.33	3.21	3.09	2.97	2.86	2.74	2.48	2.23	2.03	1.83	1.54	1.29	0.86	0.62	0.25	0.15	0.09	1.00	74.3	69.4	2.35	1.30	0.30
.018	3.72	3.40	3.28	3.16	3.03	2.92	2.80	2.53	2.28	2.08	1.88	1.59	1.36	0.91	0.67	0.26	0.17	0.10	1.00	77.3	75.4	2.40	1.30	0.32
.020	3.81	3.48	3.35	3.23	3.10	2.98	2.86	2.59	2.33	2.13	1.93	1.63	1.40	0.97	0.71	0.29	0.18	0.10	1.00	80.4	81.2	2.45	1.29	0.35
.022	3.89	3.56	3.43	3.29	3.17	3.04	2.92	2.64	2.38	2.19	1.98	1.68	1.44	1.03	0.76	0.31	0.19	0.11	1.00	83.4	86.8	2.50	1.29	0.37
.024	3.98	3.63	3.50	3.36	3.23	3.11	2.98	2.70	2.43	2.24	2.03	1.72	1.49	1.09	0.80	0.33	0.21	0.11	1.00	86.5	92.2	2.55	1.28	0.40
.026	4.06	3.71	3.57	3.43	3.30	3.17	3.04	2.76	2.48	2.29	2.08	1.77	1.53	1.14	0.84	0.35	0.22	0.12	1.00	89.5	97.4	2.60	1.28	0.42
.028	4.15	3.78	3.64	3.50	3.36	3.23	3.10	2.81	2.53	2.34	2.13	1.81	1.57	1.20	0.88	0.37	0.23	0.13	1.00	92.5	102.4	2.65	1.27	0.45
.030	4.23	3.86	3.71	3.56	3.43	3.29	3.16	2.87	2.58	2.38	2.18	1.85	1.61	1.23	0.93	0.39	0.24	0.14	1.00	95.6	107.3	2.70	1.27	0.47
.032	4.32	3.93	3.78	3.63	3.49	3.36	3.22	2.92	2.63	2.43	2.23	1.89	1.64	1.26	0.96	0.41	0.25	0.15	1.00	98.6	112.1	2.75	1.26	0.49
.034	4.40	4.01	3.86	3.70	3.56	3.42	3.28	2.98	2.68	2.48	2.24	1.94	1.68	1.32	1.01	0.42	0.27	0.15	1.01	101.6	116.8	2.79	1.26	0.52
.036	4.49	4.08	3.93	3.77	3.62	3.48	3.34	3.03	2.73	2.53	2.29	1.98	1.71	1.35	1.05	0.44	0.28	0.16	1.02	104.7	121.4	2.84	1.25	0.54
.038	4.57	4.16	4.00	3.84	3.69	3.55	3.40	3.09	2.79	2.58	2.33	2.01	1.75	1.39	1.09	0.46	0.29	0.17	1.04	107.7	125.9	2.89	1.25	0.56
.040	4.66	4.23	4.07	3.90	3.75	3.61	3.46	3.14	2.84	2.63	2.38	2.05	1.79	1.43	1.13	0.48	0.30	0.17	1.05	110.8	130.3	2.94	1.24	0.59
.042	4.74	4.31	4.14	3.97	3.82	3.67	3.52	3.20	2.89	2.68	2.42	2.09	1.83	1.45	1.17	0.50	0.31	0.18	1.07	113.8	134.6	2.99	1.24	0.61
.044	4.83	4.38	4.21	4.04	3.88	3.73	3.58	3.26	2.94	2.72	2.47	2.13	1.87	1.48	1.21	0.52	0.33	0.19	1.08	116.8	138.9	3.04	1.23	0.64
.046	4.91	4.46	4.28	4.11	3.95	3.80	3.64	3.31	2.99	2.77	2.51	2.18	1.90	1.52	1.22	0.54	0.34	0.19	1.09	119.9	143.1	3.09	1.23	0.66
.048	5.00	4.53	4.36	4.17	4.01	3.86	3.70	3.37	3.04	2.82	2.56	2.22	1.94	1.55	1.26	0.55	0.35	0.20	1.11	122.9	147.2	3.14	1.22	0.68
.050	5.08	4.61	4.43	4.24	4.08	3.92	3.76	3.42	3.09	2.87	2.60	2.25	1.98	1.58	1.30	0.57	0.36	0.21	1.12	125.9	151.3	3.18	1.22	0.71
.052	5.17	4.68	4.50	4.31	4.15	3.98	3.82	3.48	3.15	2.91	2.65	2.28	2.01	1.61	1.33	0.59	0.37	0.21	1.14	129.0	155.3	3.23	1.21	0.73
.054	5.25	4.76	4.57	4.37	4.21	4.05	3.87	3.53	3.20	2.96	2.69	2.31	2.05	1.64	1.36	0.61	0.38	0.22	1.15	132.0	159.2	3.28	1.21	0.75
.056	5.34	4.83	4.64	4.44	4.28	4.11	3.93	3.59	3.25	3.01	2.74	2.35	2.09	1.66	1.38	0.63	0.40	0.23	1.16	135.1	163.2	3.33	1.20	0.78
.058	5.42	4.91	4.71	4.51	4.34	4.17	3.99	3.64	3.30	3.06	2.78	2.40	2.11	1.69	1.41	0.65	0.41	0.23	1.18	138.1	167.1	3.38	1.20	0.80
.060	5.51	4.98	4.78	4.58	4.41	4.23	4.05	3.70	3.35	3.10	2.83	2.44	2.14	1.72	1.44	0.67	0.42	0.24	1.19	141.1	170.9	3.43	1.19	0.82
.062	5.59	5.06	4.85	4.64	4.47	4.30	4.11	3.75	3.40	3.15	2.87	2.49	2.18	1.75	1.47	0.68	0.43	0.25	1.20	144.2	174.7	3.48	1.19	0.85
.064	5.68	5.13	4.93	4.71	4.54	4.36	4.17	3.81	3.45	3.20	2.92	2.53	2.22	1.78	1.49	0.70	0.44	0.26	1.21	147.2	178.5	3.53	1.18	0.87
.066	5.76	5.21	5.00	4.78	4.60	4.42	4.23	3.86	3.50	3.24	2.96	2.57	2.25	1.81	1.52	0.72	0.45	0.26	1.23	150.2	182.2	3.58	1.18	0.89
.068	5.84	5.28	5.07	4.85	4.67	4.48	4.29	3.92	3.56	3.29	3.00	2.58	2.29	1.84	1.54	0.74	0.47	0.27	1.24	153.3	185.9	3.62	1.17	0.91
.070	5.93	5.36	5.14	4.91	4.73	4.55	4.35	3.98	3.61	3.34	3.05	2.62	2.32	1.87	1.56	0.76	0.48	0.28	1.25	156.3	189.6	3.67	1.17	0.94
.072	6.01	5.43	5.21	4.98	4.80	4.61	4.41	4.03	3.66	3.38	3.09	2.66	2.36	1.90	1.59	0.78	0.49	0.28	1.26	159.4	193.2	3.72	1.16	0.96
.074	6.10	5.51	5.28	5.05	4.86	4.67	4.47	4.09	3.71	3.43	3.14	2.70	2.39	1.92	1.61	0.79	0.50	0.29	1.27	162.4	196.8	3.77	1.16	0.98
.076	6.18	5.58	5.35	5.12	4.93	4.73	4.53	4.14	3.76	3.48	3.18	2.74	2.43	1.95	1.64	0.81	0.51	0.30	1.29	165.4	200.4	3.82	1.15	1.01
.078	6.27	5.66	5.42	5.18	4.99	4.80	4.59	4.20	3.81	3.52	3.23	2.78	2.46	1.98	1.66	0.83	0.53	0.30	1.30	168.5	204.0	3.87	1.15	1.03
.080	6.35	5.73	5.49	5.25	5.06	4.86	4.65	4.25	3.86	3.57	3.27	2.82	2.49	2.01	1.69	0.85	0.54	0.31	1.31	171.5	207.6	3.92	1.14	1.05

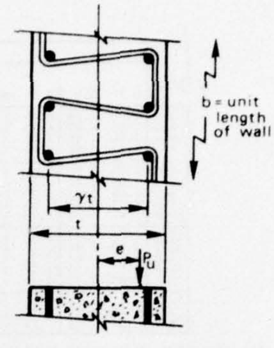
p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6 — VALUES OF ECCENTRICITY RATIO 6e/t																		Eff. t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	3.35	3.06	2.95	2.83	2.72	2.61	2.51	2.26	2.03	1.85	1.65	1.35	1.06	0.65	0.44	0.17	0.10	0.06	1.00	77.0	61.0	2.41	1.47	0.21
.012	3.44	3.14	3.02	2.90	2.79	2.68	2.57	2.33	2.09	1.91	1.73	1.41	1.16	0.73	0.51	0.19	0.12	0.07	1.00	82.4	70.5	2.46	1.46	0.25
.014	3.52	3.21	3.10	2.98	2.86	2.75	2.64	2.39	2.15	1.98	1.80	1.46	1.24	0.81	0.57	0.22	0.13	0.08	1.00	87.8	79.5	2.51	1.46	0.28
.016	3.61	3.29	3.17	3.05	2.93	2.82	2.71	2.45	2.22	2.04	1.86	1.53	1.31	0.89	0.63	0.24	0.15	0.08	1.00	93.2	88.2	2.56	1.46	0.31
.018	3.69	3.37	3.24	3.12	2.99	2.89	2.77	2.52	2.28	2.09	1.93	1.60	1.37	0.96	0.68	0.27	0.16	0.09	1.00	98.6	96.5	2.61	1.45	0.34
.020	3.78	3.44	3.32	3.19	3.06	2.95	2.84	2.58	2.35	2.15	1.96	1.66	1.40	1.04	0.74	0.29	0.18	0.10	1.02	104.0	104.6	2.66	1.45	0.37
.022	3.86	3.52	3.39	3.26	3.13	3.02	2.91	2.64	2.41	2.20	2.01	1.72	1.44	1.09	0.80	0.31	0.19	0.11	1.05	109.4	112.5	2.70	1.45	0.41
.024	3.95	3.60	3.47	3.34	3.20	3.09	2.97	2.70	2.47	2.25	2.07	1.77	1.49	1.16	0.86	0.34	0.21	0.12	1.07	114.8	120.1	2.75	1.44	0.44
.026	4.03	3.67	3.54	3.41	3.27	3.15	3.04	2.76	2.53	2.30	2.12	1.83	1.55	1.22	0.91	0.36	0.22	0.13	1.10	120.2	127.6	2.80	1.44	0.47
.028	4.12	3.75	3.61	3.48	3.34	3.22	3.10	2.82	2.59	2.35	2.17	1.89	1.61	1.27	0.97	0.39	0.24	0.14	1.12	125.6	135.0	2.85	1.44	0.50
.030	4.21	3.83	3.69	3.55	3.41	3.29	3.17	2.87	2.65	2.41	2.23	1.92	1.66	1.31	1.02	0.41	0.25	0.14	1.14	131.0	142.2	2.90	1.43	0.53
.032	4.29	3.90	3.76	3.62	3.48	3.35	3.23	2.93	2.71	2.47	2.28	1.96	1.71	1.34	1.06	0.43	0.27	0.15	1.17	136.4	149.3	2.95	1.43	0.56
.034	4.30	3.98	3.84	3.69	3.55	3.42	3.30	2.99	2.76	2.52	2.35	2.01	1.76	1.36	1.11	0.46	0.28	0.16	1.19	141.8	156.2	3.00	1.43	0.59
.036	4.46	4.06	3.91	3.77	3.62	3.49	3.36	3.05	2.82	2.58	2.40	2.06	1.81	1.39	1.16	0.48	0.30	0.17	1.21	147.2	163.1	3.05	1.42	0.63
.038	4.55	4.14	3.98	3.84	3.69	3.55	3.43	3.11	2.88	2.64	2.45	2.11	1.85	1.40	1.20	0.50	0.31	0.18	1.24	152.6	169.8	3.09	1.42	0.66
.040	4.64	4.21	4.06	3.91	3.76	3.62	3.49	3.17	2.94	2.70	2.50	2.16	1.91	1.42	1.24	0.53	0.33	0.19	1.26	158.0	176.5	3.14	1.42	0.69
.042	4.72	4.29	4.13	3.98	3.83	3.68	3.56	3.23	2.99	2.75	2.54	2.20	1.93	1.48	1.28	0.55	0.34	0.19	1.28	163.4	183.1	3.19	1.42	0.72
.044	4.81	4.37	4.21	4.05	3.90	3.75	3.62	3.30	3.05	2.81	2.59	2.25	1.98	1.53	1.30	0.57	0.36	0.20	1.30	168.8	189.6	3.24	1.41	0.75
.046	4.90	4.44	4.28	4.12	3.97	3.81	3.69	3.36	3.11	2.86	2.63	2.30	2.02	1.58	1.32	0.60	0.37	0.21	1.32	174.2	196.1	3.29	1.41	0.78
.048	4.98	4.52	4.35	4.20	4.04	3.88	3.75	3.42	3.16	2.92	2.68	2.34	2.06	1.62	1.34	0.62	0.39	0.22	1.34	179.6	202.5	3.34	1.41	0.81
.050	5.07	4.60	4.43	4.27	4.10	3.95	3.82	3.48	3.22	2.98	2.72	2.39	2.10	1.67	1.35	0.64	0.40	0.23	1.36	185.0	208.8	3.39	1.40	0.84
.052	5.15	4.68	4.50	4.34	4.17	4.01	3.88	3.54	3.27	3.03	2.77	2.43	2.14	1.71	1.36	0.67	0.41	0.24	1.38	190.4	215.1	3.44	1.40	0.87
.054	5.24	4.75	4.57	4.41	4.24	4.08	3.95	3.60	3.33	3.09	2.83	2.48	2.19	1.75	1.38	0.69	0.43	0.24	1.40	195.8	221.4	3.49	1.40	0.90
.056	5.33	4.83	4.65	4.48	4.31	4.14	4.01	3.66	3.38	3.09	2.88	2.52	2.23	1.79	1.39	0.71	0.44	0.25	1.42	201.2	227.5	3.53	1.39	0.94
.058	5.41	4.91	4.72	4.55	4.38	4.21	4.07	3.72	3.44	3.15	2.93	2.57	2.27	1.83	1.41	0.74	0.46	0.26	1.44	206.6	233.7	3.58	1.39	0.97
.060	5.50	4.98	4.79	4.63	4.45	4.27	4.14	3.78	3.49	3.20	2.99	2.61	2.31	1.87	1.46	0.76	0.47	0.27	1.46	212.0	239.8	3.63	1.39	1.00
.062	5.59	5.06	4.87	4.70	4.52	4.34	4.20	3.85	3.55	3.25	3.04	2.66	2.35	1.90	1.51	0.78	0.49	0.28	1.47	217.4	245.9	3.68	1.38	1.03
.064	5.67	5.14	4.94	4.77	4.59	4.40	4.27	3.91	3.60	3.30	3.09	2.70	2.40	1.94	1.55	0.81	0.50	0.29	1.49	222.8	251.9	3.73	1.38	1.06
.066	5.76	5.22	5.02	4.84	4.66	4.47	4.33	3.97	3.66	3.36	3.15	2.74	2.44	1.97	1.59	0.83	0.52	0.29	1.51	228.2	257.9	3.78	1.38	1.09
.068	5.84	5.29	5.09	4.91	4.73	4.54	4.40	4.03	3.71	3.41	3.20	2.79	2.48	2.00	1.63	0.85	0.53	0.30	1.53	233.6	263.8	3.83	1.37	1.12
.070	5.93	5.37	5.16	4.98	4.80	4.60	4.46	4.09	3.77	3.46	3.25	2.83	2.50	2.04	1.67	0.88	0.55	0.31	1.55	239.0	269.8	3.88	1.37	1.15
.072	6.02	5.45	5.24	5.05	4.87	4.67	4.52	4.15	3.82	3.51	3.26	2.88	2.54	2.08	1.71	0.90	0.56	0.32	1.56	244.4	275.7	3.92	1.37	1.18
.074	6.10	5.53	5.31	5.13	4.94	4.74	4.59	4.21	3.88	3.56	3.31	2.92	2.58	2.10	1.74	0.92	0.58	0.33	1.58	249.8	281.6	3.97	1.36	1.22
.076	6.19	5.60	5.38	5.20	5.00	4.80	4.65	4.27	3.93	3.62	3.36	2.96	2.62	2.13	1.78	0.94	0.59	0.34	1.60	255.2	287.4	4.02	1.36	1.25
.078	6.28	5.68	5.46	5.27	5.07	4.87	4.71	4.33	3.98	3.67	3.40	3.00	2.66	2.17	1.81	0.96	0.61	0.34	1.61	260.6	293.2	4.07	1.36	1.28
.080	6.36	5.76	5.53	5.34	5.14	4.94	4.78	4.39	4.04	3.72	3.45	3.05	2.70	2.20	1.85	0.99	0.62	0.35	1.63	266.0	299.0	4.12	1.35	1.31

L/t_e	VALUES OF MOMENT MULTIPLIERS δ																					
	VALUES OF ULTIMATE STRESS P_u/A_g IN KSI																					
	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.03	1.04
3.0	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.06	1.07	1.08	1.09
4.0	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.05	1.08	1.09	1.11	1.12	1.13	1.15	1.16
5.0	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.08	1.13	1.16	1.18	1.20	1.23	1.25	1.28
6.0	1.01	1.01	1.02	1.03	1.04	1.05	1.05	1.06	1.07	1.08	1.09	1.10	1.10	1.11	1.12	1.21	1.24	1.28	1.32	1.37	1.41	1.46
7.0	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.11	1.12	1.14	1.15	1.16	1.18	1.30	1.36	1.42	1.49	1.57	1.66	1.76
8.0	1.01	1.03	1.04	1.05	1.07	1.08	1.10	1.12	1.13	1.15	1.17	1.18	1.20	1.22	1.24	1.43	1.53	1.64	1.76	1.91	2.08	2.28
9.0	1.02	1.03	1.05	1.07	1.09	1.11	1.13	1.15	1.17	1.20	1.22	1.25	1.27	1.30	1.33	1.62	1.78	1.97	2.21	2.51	2.91	3.46
10.0	1.02	1.04	1.06	1.09	1.11	1.14	1.17	1.19	1.22	1.25	1.29	1.32	1.36	1.40	1.44	1.90	2.18	2.55	3.08	3.89	5.28	8.20
11.0	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.32	1.37	1.42	1.47	1.52	1.58	2.34	2.89	3.78	5.47	9.91		
12.0	1.03	1.06	1.10	1.13	1.17	1.21	1.26	1.30	1.36	1.41	1.47	1.54	1.61	1.69	1.78	3.13	4.51	8.03				
13.0	1.04	1.07	1.11	1.16	1.21	1.26	1.32	1.38	1.45	1.52	1.60	1.70	1.80	1.92	2.06	4.98						
14.0	1.04	1.09	1.14	1.19	1.25	1.31	1.39	1.47	1.56	1.66	1.78	1.91	2.07	2.25	2.47							
15.0	1.05	1.10	1.16	1.22	1.30	1.38	1.47	1.57	1.70	1.84	2.01	2.21	2.46	2.76	3.16							
16.0	1.05	1.12	1.18	1.26	1.35	1.45	1.57	1.71	1.88	2.08	2.33	2.65	3.07	3.65	4.51							
17.0	1.06	1.13	1.21	1.31	1.41	1.54	1.69	1.88	2.11	2.41	2.81	3.36	4.19	5.55	8.23							
18.0	1.07	1.15	1.25	1.36	1.49	1.65	1.85	2.11	2.44	2.91	3.60	4.71	6.83									

p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .75																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	VALUES OF ECCENTRICITY RATIO 6e/t																							
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	3.34	3.03	2.92	2.80	2.69	2.58	2.48	2.24	2.01	1.84	1.67	1.32	1.03	0.65	0.44	0.16	0.10	0.05	1.00	92.2	76.0	2.61	1.61	0.22
.012	3.43	3.11	3.00	2.88	2.76	2.66	2.55	2.31	2.09	1.91	1.75	1.42	1.14	0.75	0.51	0.19	0.12	0.06	1.00	100.6	88.5	2.66	1.60	0.26
.014	3.52	3.19	3.07	2.96	2.84	2.73	2.63	2.38	2.16	1.98	1.83	1.51	1.24	0.83	0.58	0.22	0.13	0.08	1.04	109.1	100.4	2.71	1.60	0.30
.016	3.61	3.27	3.15	3.03	2.91	2.80	2.70	2.44	2.24	2.04	1.87	1.59	1.32	0.92	0.66	0.25	0.15	0.08	1.08	117.5	112.1	2.76	1.60	0.34
.018	3.70	3.35	3.23	3.11	2.99	2.87	2.77	2.51	2.31	2.10	1.96	1.68	1.40	0.99	0.72	0.27	0.17	0.09	1.12	125.9	123.4	2.81	1.59	0.38
.020	3.78	3.43	3.30	3.18	3.06	2.94	2.84	2.58	2.37	2.17	2.02	1.72	1.48	1.05	0.78	0.30	0.18	0.10	1.16	134.4	134.4	2.86	1.59	0.41
.022	3.87	3.51	3.38	3.26	3.14	3.01	2.91	2.65	2.44	2.24	2.07	1.78	1.55	1.13	0.85	0.33	0.20	0.11	1.20	142.8	145.2	2.91	1.59	0.45
.024	3.96	3.59	3.46	3.33	3.21	3.08	2.98	2.72	2.50	2.31	2.12	1.84	1.62	1.20	0.90	0.36	0.22	0.12	1.23	151.2	155.8	2.96	1.58	0.49
.026	4.05	3.67	3.53	3.41	3.29	3.16	3.05	2.79	2.56	2.37	2.17	1.89	1.66	1.26	0.95	0.38	0.24	0.13	1.26	159.7	166.2	3.01	1.58	0.53
.028	4.14	3.75	3.61	3.48	3.36	3.23	3.12	2.86	2.62	2.43	2.23	1.95	1.71	1.31	1.01	0.41	0.25	0.14	1.30	168.1	176.5	3.05	1.58	0.57
.030	4.23	3.83	3.69	3.56	3.43	3.30	3.18	2.92	2.68	2.50	2.30	2.00	1.76	1.38	1.07	0.44	0.27	0.15	1.33	176.6	186.6	3.10	1.57	0.61
.032	4.32	3.91	3.76	3.63	3.51	3.38	3.25	2.99	2.74	2.56	2.36	2.05	1.81	1.43	1.12	0.47	0.29	0.16	1.36	185.0	196.6	3.15	1.57	0.65
.034	4.41	3.99	3.84	3.71	3.58	3.45	3.32	3.06	2.80	2.62	2.42	2.10	1.86	1.48	1.18	0.50	0.30	0.17	1.39	193.4	206.5	3.20	1.57	0.69
.036	4.49	4.07	3.92	3.78	3.65	3.52	3.38	3.12	2.85	2.67	2.45	2.15	1.91	1.53	1.22	0.53	0.32	0.18	1.42	201.9	216.3	3.25	1.56	0.73
.038	4.58	4.15	4.00	3.85	3.72	3.59	3.45	3.19	2.92	2.73	2.51	2.20	1.96	1.59	1.27	0.55	0.34	0.19	1.45	210.3	226.0	3.30	1.56	0.77
.040	4.67	4.23	4.07	3.93	3.80	3.66	3.52	3.25	2.98	2.79	2.56	2.27	2.01	1.63	1.31	0.58	0.36	0.20	1.48	218.8	235.5	3.35	1.56	0.80
.042	4.76	4.31	4.15	4.00	3.87	3.73	3.59	3.32	3.05	2.84	2.62	2.31	2.06	1.67	1.36	0.61	0.37	0.21	1.51	227.2	245.1	3.40	1.55	0.84
.044	4.85	4.39	4.23	4.07	3.94	3.80	3.66	3.38	3.11	2.90	2.67	2.35	2.09	1.71	1.40	0.64	0.39	0.22	1.54	235.6	254.5	3.44	1.55	0.88
.046	4.94	4.47	4.31	4.14	4.01	3.87	3.73	3.45	3.17	2.95	2.73	2.39	2.13	1.75	1.45	0.66	0.41	0.23	1.56	244.1	263.9	3.49	1.55	0.92
.048	5.02	4.55	4.38	4.22	4.08	3.95	3.80	3.51	3.24	3.01	2.78	2.45	2.18	1.79	1.48	0.69	0.43	0.24	1.59	252.5	273.2	3.54	1.54	0.96
.050	5.11	4.62	4.46	4.29	4.15	4.02	3.87	3.57	3.30	3.06	2.84	2.50	2.22	1.82	1.52	0.71	0.44	0.25	1.62	260.9	282.4	3.59	1.54	1.00
.052	5.20	4.70	4.54	4.37	4.23	4.09	3.94	3.64	3.36	3.11	2.89	2.56	2.28	1.85	1.57	0.74	0.46	0.26	1.64	269.4	291.6	3.64	1.54	1.04
.054	5.28	4.78	4.61	4.44	4.30	4.16	4.01	3.70	3.42	3.16	2.94	2.58	2.32	1.89	1.60	0.76	0.48	0.27	1.67	277.8	300.7	3.69	1.54	1.08
.056	5.37	4.86	4.69	4.52	4.37	4.23	4.08	3.76	3.48	3.21	3.00	2.63	2.36	1.93	1.64	0.79	0.49	0.28	1.69	286.3	309.8	3.74	1.53	1.12
.058	5.45	4.94	4.77	4.59	4.44	4.30	4.15	3.82	3.55	3.27	3.05	2.68	2.41	1.97	1.67	0.81	0.51	0.29	1.72	294.7	318.9	3.79	1.53	1.15
.060	5.53	5.02	4.84	4.67	4.51	4.37	4.22	3.89	3.61	3.32	3.10	2.73	2.45	2.01	1.70	0.84	0.53	0.30	1.74	303.1	327.9	3.84	1.53	1.19
.062	5.61	5.10	4.92	4.74	4.58	4.44	4.29	3.95	3.67	3.37	3.16	2.77	2.49	2.05	1.74	0.86	0.55	0.31	1.77	311.6	336.9	3.88	1.52	1.23
.064	5.70	5.18	5.00	4.82	4.65	4.51	4.35	4.01	3.73	3.43	3.21	2.82	2.54	2.08	1.76	0.89	0.56	0.32	1.79	320.0	345.8	3.93	1.52	1.27
.066	5.78	5.25	5.08	4.89	4.72	4.57	4.42	4.07	3.79	3.49	3.26	2.87	2.57	2.12	1.79	0.91	0.58	0.33	1.81	328.4	354.7	3.98	1.52	1.31
.068	5.86	5.33	5.15	4.97	4.79	4.64	4.49	4.13	3.85	3.55	3.31	2.92	2.60	2.16	1.83	0.94	0.60	0.34	1.84	336.9	363.5	4.03	1.51	1.35
.070	5.94	5.41	5.23	5.04	4.86	4.71	4.56	4.19	3.91	3.61	3.40	2.97	2.65	2.20	1.86	0.96	0.61	0.35	1.86	345.3	372.4	4.08	1.51	1.39
.072	6.03	5.49	5.30	5.11	4.93	4.78	4.63	4.25	3.97	3.67	3.45	3.02	2.70	2.22	1.89	0.99	0.63	0.36	1.88	353.7	381.2	4.13	1.51	1.43
.074	6.11	5.57	5.38	5.19	5.00	4.85	4.70	4.31	4.03	3.73	3.49	3.06	2.75	2.26	1.92	1.01	0.65	0.37	1.90	362.2	389.9	4.18	1.50	1.47
.076	6.19	5.65	5.46	5.26	5.07	4.92	4.76	4.37	4.09	3.79	3.54	3.11	2.77	2.29	1.96	1.03	0.66	0.38	1.93	370.6	398.7	4.23	1.50	1.50
.078	6.27	5.72	5.53	5.34	5.14	4.99	4.83	4.43	4:15	3.84	3.59	3.16	2.81	2.33	1.99	1.06	0.68	0.39	1.95	379.1	407.4	4.27	1.50	1.54
.080	6.36	5.80	5.61	5.41	5.21	5.06	4.90	4.49	4.21	3.90	3.64	3.21	2.86	2.37	2.01	1.08	0.69	0.40	1.97	387.5	416.1	4.32	1.49	1.58

p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .9																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	VALUES OF ECCENTRICITY RATIO 6e/t																							
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	3.34	3.02	2.90	2.79	2.67	2.57	2.46	2.22	2.01	1.80	1.64	1.29	1.02	0.65	0.45	0.16	0.10	0.06	1.05	110.8	94.3	2.82	1.74	0.24
.012	3.44	3.11	2.98	2.87	2.75	2.65	2.55	2.30	2.10	1.90	1.71	1.41	1.13	0.75	0.52	0.20	0.12	0.07	1.11	122.9	110.3	2.87	1.74	0.28
.014	3.53	3.19	3.07	2.95	2.84	2.72	2.62	2.38	2.18	1.99	1.79	1.51	1.23	0.84	0.60	0.23	0.14	0.08	1.16	135.1	125.9	2.92	1.74	0.33
.016	3.63	3.27	3.15	3.03	2.92	2.80	2.70	2.46	2.26	2.07	1.88	1.60	1.32	0.93	0.67	0.26	0.16	0.09	1.21	147.2	141.1	2.96	1.73	0.38
.018	3.72	3.36	3.23	3.11	3.00	2.88	2.78	2.54	2.33	2.15	1.96	1.66	1.41	1.00	0.74	0.29	0.18	0.10	1.26	159.4	156.0	3.01	1.73	0.43
.020	3.81	3.44	3.31	3.1[illegible]	3.08	2.96	2.85	2.61	2.39	2.22	2.04	1.71	1.50	1.07	0.81	0.32	0.20	0.11	1.31	171.5	170.6	3.06	1.73	0.47
.022	3.90	3.52	3.39	3.27	3.15	3.04	2.92	2.69	2.46	2.29	2.12	1.78	1.58	1.16	0.87	0.35	0.22	0.12	1.36	183.6	185.0	3.11	1.73	0.52
.024	4.00	3.61	3.47	3.34	3.23	3.12	3.00	2.76	2.52	2.36	2.19	1.86	1.63	1.23	0.93	0.38	0.24	0.13	1.40	195.8	199.1	3.16	1.72	0.57
.026	4.09	3.69	3.56	3.42	3.31	3.19	3.08	2.83	2.60	2.42	2.23	1.93	1.67	1.29	1.00	0.41	0.25	0.14	1.44	207.9	213.1	3.21	1.72	0.61
.028	4.18	3.77	3.64	3.50	3.38	3.27	3.15	2.90	2.67	2.48	2.29	2.00	1.70	1.36	1.05	0.44	0.27	0.15	1.48	220.1	227.0	3.26	1.72	0.66
.030	4.25	3.85	3.72	3.58	3.46	3.34	3.23	2.97	2.74	2.54	2.35	2.06	1.76	1.42	1.11	0.47	0.29	0.16	1.52	232.2	240.7	3.31	1.71	0.71
.032	4.33	3.93	3.80	3.66	3.53	3.42	3.30	3.04	2.81	2.59	2.41	2.13	1.83	1.49	1.17	0.50	0.31	0.17	1.56	244.4	254.2	3.35	1.71	0.75
.034	4.41	4.01	3.88	3.74	3.60	3.49	3.37	3.10	2.88	2.65	2.47	2.17	1.90	1.54	1.22	0.53	0.33	0.19	1.60	256.5	267.7	3.40	1.71	0.80
.036	4.48	4.09	3.96	3.82	3.68	3.56	3.45	3.17	2.95	2.71	2.56	2.22	1.96	1.59	1.27	0.56	0.35	0.20	1.64	268.7	281.0	3.45	1.70	0.85
.038	4.56	4.17	4.04	3.89	3.75	3.64	3.52	3.23	3.01	2.78	2.61	2.28	2.02	1.62	1.32	0.59	0.37	0.21	1.68	280.8	294.2	3.50	1.70	0.89
040	4.65	4.25	4.11	3.97	3.83	3.71	3.59	3.29	3.08	2.85	2.66	2.33	2.08	1.64	1.38	0.62	0.39	0.22	1.71	293.0	307.4	3.55	1.70	0.94
.042	4.74	4.33	4.19	4.05	3.90	3.78	3.66	3.36	3.14	2.92	2.71	2.39	2.14	1.66	1.43	0.65	0.41	0.23	1.75	305.2	320.4	3.60	1.69	0.99
.044	4.83	4.42	4.27	4.13	3.98	3.85	3.73	3.43	3.20	2.98	2.76	2.44	2.17	1.68	1.48	0.68	0.42	0.24	1.78	317.3	333.4	3.65	1.69	1.03
.046	4.92	4.50	4.35	4.20	4.06	3.92	3.80	3.50	3.26	3.04	2.81	2.49	2.22	1.73	1.52	0.71	0.44	0.25	1.82	329.5	346.4	3.70	1.69	1.08
.048	5.01	4.59	4.43	4.28	4.13	3.99	3.87	3.57	3.33	3.11	2.88	2.55	2.27	1.79	1.56	0.73	0.46	0.26	1.85	341.6	359.2	3.75	1.68	1.13
.050	5.10	4.67	4.50	4.36	4.21	4.06	3.94	3.64	3.39	3.17	2.94	2.60	2.32	1.85	1.58	0.76	0.48	0.27	1.88	353.7	372.0	3.79	1.68	1.17
.052	5.18	4.76	4.58	4.43	4.28	4.13	4.01	3.71	3.45	3.23	3.00	2.65	2.37	1.91	1.60	0.79	0.50	0.28	1.91	365.9	384.7	3.84	1.68	1.22
.054	5.27	4.84	4.66	4.51	4.36	4.20	4.08	3.78	3.51	3.29	3.06	2.70	2.42	1.96	1.62	0.82	0.52	0.29	1.94	378.0	397.4	3.89	1.67	1.27
.056	5.36	4.92	4.74	4.59	4.44	4.28	4.15	3.85	3.57	3.35	3.12	2.75	2.46	2.01	1.63	0.84	0.53	0.30	1.98	390.2	410.1	3.94	1.67	1.31
.058	5.45	5.01	4.81	4.66	4.51	4.35	4.22	3.92	3.62	3.41	3.19	2.80	2.51	2.05	1.65	0.87	0.55	0.31	2.01	402.3	422.6	3.99	1.67	1.36
.060	5.54	5.09	4.89	4.74	4.59	4.43	4.29	3.98	3.68	3.47	3.25	2.85	2.56	2.10	1.66	0.90	0.57	0.33	2.04	414.5	435.2	4.04	1.66	1.41
.062	5.62	5.17	4.97	4.81	4.66	4.50	4.36	4.05	3.74	3.53	3.26	2.90	2.61	2.14	1.71	0.93	0.59	0.34	2.07	426.7	447.7	4.09	1.66	1.45
.064	5.71	5.26	5.04	4.89	4.73	4.57	4.42	4.12	3.80	3.59	3.32	2.95	2.66	2.19	1.76	0.95	0.61	0.35	2.09	438.8	460.2	4.14	1.66	1.50
.066	5.80	5.34	5.13	4.97	4.81	4.65	4.49	4.18	3.86	3.64	3.38	3.02	2.70	2.24	1.81	0.98	0.63	0.36	2.12	451.0	472.6	4.18	1.66	1.55
.068	5.89	5.42	5.21	5.04	4.88	4.72	4.56	4.25	3.92	3.70	3.43	3.06	2.75	2.26	1.86	1.01	0.64	0.37	2.15	463.1	485.0	4.23	1.65	1.59
.070	5.98	5.51	5.29	5.12	4.96	4.79	4.63	4.32	3.99	3.76	3.49	3.11	2.80	2.30	1.91	1.03	0.66	0.38	2.18	475.2	497.4	4.28	1.65	1.64
.072	6.06	5.59	5.37	5.19	5.03	4.87	4.70	4.38	4.05	3.81	3.54	3.15	2.84	2.34	1.95	1.06	0.68	0.39	2.21	487.4	509.7	4.33	1.65	1.69
.074	6.15	5.67	5.45	5.27	5.10	4.94	4.77	4.45	4.12	3.87	3.60	3.19	2.89	2.38	1.99	1.08	0.70	0.40	2.24	499.5	522.0	4.38	1.64	1.73
.076	6.24	5.75	5.53	5.34	5.18	5.01	4.84	4.51	4.18	3.92	3.65	3.24	2.93	2.42	2.04	1.11	0.71	0.41	2.26	511.7	534.3	4.43	1.64	1.78
.078	6.33	5.84	5.61	5.41	5.25	5.09	4.91	4.58	4.25	3.98	3.71	3.29	2.98	2.46	2.08	1.13	0.73	0.42	2.29	523.8	546.6	4.48	1.64	1.83
.080	6.42	5.92	5.69	5.49	5.33	5.16	4.98	4.64	4.31	4.04	3.76	3.35	3.02	2.50	2.12	1.16	0.75	0.43	2.32	536.0	558.8	4.53	1.63	1.87

Table 6.6A.2 Values of ultimate axial stress, P_u/A_g, for rectangular column with symmetric reinforcing steel, f'_c = 4 ksi, f_{dy} = 52 ksi, γ = 0.45, 0.60, 0.75, 0.90



p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .45																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	VALUES OF ECCENTRICITY RATIO $\delta e/t$																							
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	4.36	4.00	3.86	3.72	3.58	3.45	3.31	2.98	2.67	2.39	2.16	1.72	1.31	0.79	0.54	0.21	0.13	0.07	1.00	81.9	52.7	2.86	1.76	0.24
.012	4.44	4.08	3.94	3.79	3.65	3.51	3.37	3.04	2.72	2.45	2.21	1.80	1.38	0.85	0.60	0.23	0.14	0.08	1.00	84.9	60.6	2.91	1.75	0.27
.014	4.53	4.15	4.01	3.86	3.71	3.57	3.43	3.09	2.78	2.50	2.26	1.87	1.48	0.93	0.65	0.25	0.16	0.09	1.00	87.9	68.0	2.95	1.75	0.30
.016	4.61	4.23	4.08	3.93	3.77	3.63	3.49	3.15	2.83	2.56	2.31	1.91	1.55	0.98	0.70	0.27	0.17	0.10	1.00	91.0	75.1	3.00	1.74	0.33
.018	4.69	4.30	4.15	3.99	3.84	3.69	3.54	3.20	2.88	2.61	2.35	1.96	1.62	1.05	0.75	0.30	0.18	0.10	1.00	94.0	81.8	3.05	1.74	0.35
.020	4.78	4.37	4.22	4.06	3.90	3.75	3.60	3.26	2.93	2.66	2.40	2.01	1.68	1.11	0.80	0.32	0.20	0.11	1.00	97.0	88.3	3.10	1.73	0.38
.022	4.86	4.45	4.29	4.13	3.97	3.82	3.66	3.31	2.98	2.71	2.44	2.06	1.73	1.17	0.84	0.34	0.21	0.12	1.00	100.1	94.5	3.14	1.72	0.41
.024	4.95	4.52	4.36	4.19	4.03	3.88	3.72	3.36	3.03	2.77	2.49	2.10	1.81	1.22	0.89	0.35	0.22	0.13	1.00	103.1	100.6	3.19	1.72	0.43
.026	5.03	4.60	4.43	4.26	4.09	3.94	3.78	3.42	3.08	2.82	2.54	2.15	1.84	1.27	0.93	0.38	0.24	0.13	1.00	106.2	106.4	3.24	1.71	0.46
.028	5.11	4.67	4.50	4.33	4.16	4.00	3.84	3.47	3.12	2.87	2.59	2.20	1.89	1.33	0.98	0.40	0.23	0.14	1.00	109.2	112.0	3.29	1.71	0.48
.030	5.20	4.74	4.57	4.39	4.22	4.06	3.89	3.53	3.17	2.92	2.64	2.24	1.93	1.39	1.03	0.42	0.26	0.15	1.00	112.2	117.5	3.34	1.70	0.51
.032	5.28	4.82	4.64	4.46	4.29	4.12	3.95	3.58	3.22	2.97	2.70	2.29	1.97	1.45	1.07	0.44	0.27	0.16	1.00	115.3	122.9	3.38	1.69	0.53
.034	5.36	4.89	4.71	4.53	4.35	4.18	4.01	3.64	3.27	3.01	2.75	2.33	2.02	1.50	1.10	0.46	0.29	0.16	1.00	118.3	128.1	3.43	1.69	0.55
.036	5.45	4.97	4.78	4.59	4.41	4.24	4.07	3.69	3.32	3.06	2.79	2.37	2.06	1.55	1.14	0.48	0.30	0.17	1.00	121.3	133.2	3.48	1.68	0.58
.038	5.53	5.04	4.85	4.66	4.48	4.31	4.13	3.74	3.37	3.11	2.84	2.41	2.10	1.60	1.19	0.50	0.31	0.18	1.00	124.4	138.2	3.53	1.67	0.60
.040	5.61	5.11	4.92	4.72	4.54	4.37	4.19	3.80	3.42	3.16	2.89	2.46	2.12	1.64	1.24	0.52	0.32	0.18	1.00	127.4	143.1	3.57	1.67	0.63
.042	5.70	5.19	4.99	4.79	4.61	4.43	4.24	3.85	3.47	3.21	2.94	2.50	2.16	1.66	1.27	0.53	0.34	0.19	1.00	130.5	147.9	3.62	1.66	0.65
.044	5.78	5.26	5.06	4.86	4.67	4.49	4.30	3.91	3.52	3.26	2.94	2.54	2.20	1.72	1.31	0.55	0.35	0.20	1.00	133.5	152.6	3.67	1.66	0.67
.046	5.86	5.33	5.13	4.92	4.73	4.55	4.36	3.96	3.57	3.30	2.99	2.58	2.23	1.76	1.36	0.57	0.36	0.21	1.01	136.5	157.2	3.72	1.65	0.70
.048	5.95	5.41	5.20	4.99	4.80	4.61	4.42	4.02	3.62	3.35	3.03	2.61	2.27	1.79	1.40	0.59	0.37	0.21	1.02	139.6	161.8	3.77	1.64	0.72
.050	6.03	5.48	5.27	5.06	4.86	4.67	4.48	4.07	3.67	3.40	3.07	2.65	2.31	1.83	1.44	0.61	0.38	0.22	1.03	142.6	166.2	3.81	1.64	0.75
.052	6.11	5.55	5.34	5.12	4.93	4.73	4.54	4.12	3.72	3.45	3.12	2.69	2.35	1.87	1.48	0.63	0.40	0.23	1.05	145.6	170.7	3.86	1.63	0.77
.054	6.20	5.63	5.41	5.19	4.99	4.79	4.59	4.18	3.77	3.49	3.16	2.73	2.38	1.89	1.53	0.65	0.41	0.23	1.06	148.7	175.0	3.91	1.63	0.79
.056	6.28	5.70	5.48	5.25	5.05	4.86	4.65	4.23	3.82	3.54	3.21	2.77	2.42	1.92	1.57	0.66	0.42	0.24	1.07	151.7	179.3	3.96	1.62	0.82
.058	6.36	5.78	5.55	5.32	5.12	4.92	4.71	4.29	3.87	3.59	3.25	2.80	2.46	1.95	1.59	0.68	0.43	0.25	1.08	154.8	183.6	4.00	1.61	0.84
.060	6.45	5.85	5.62	5.39	5.18	4.98	4.77	4.34	3.92	3.63	3.30	2.86	2.49	1.98	1.60	0.70	0.44	0.25	1.09	157.8	187.7	4.05	1.61	0.86
.062	6.53	5.92	5.69	5.45	5.24	5.04	4.83	4.40	3.97	3.68	3.34	2.89	2.53	2.02	1.64	0.72	0.45	0.26	1.10	160.8	191.9	4.10	1.60	0.89
.064	6.61	6.00	5.76	5.52	5.31	5.10	4.89	4.45	4.02	3.68	3.38	2.93	2.57	2.05	1.68	0.74	0.47	0.27	1.11	163.9	196.0	4.15	1.59	0.91
.066	6.70	6.07	5.83	5.58	5.37	5.16	4.94	4.50	4.07	3.72	3.43	2.96	2.60	2.08	1.71	0.75	0.48	0.27	1.12	166.9	200.0	4.19	1.59	0.93
.068	6.78	6.14	5.90	5.65	5.44	5.22	5.00	4.56	4.12	3.77	3.47	2.99	2.64	2.11	1.74	0.77	0.49	0.28	1.13	169.9	204.1	4.24	1.58	0.96
.070	6.86	6.22	5.97	5.71	5.50	5.28	5.06	4.61	4.17	3.82	3.51	3.02	2.68	2.14	1.77	0.79	0.50	0.29	1.14	173.0	208.0	4.29	1.58	0.98
.072	6.94	6.29	6.04	5.78	5.56	5.35	5.12	4.67	4.22	3.86	3.56	3.05	2.71	2.17	1.80	0.81	0.51	0.29	1.15	176.0	212.0	4.34	1.57	1.00
.074	7.03	6.36	6.11	5.85	5.63	5.41	5.18	4.72	4.27	3.91	3.60	3.10	2.73	2.19	1.82	0.83	0.52	0.30	1.16	179.1	215.9	4.39	1.56	1.03
.076	7.11	6.44	6.18	5.91	5.69	5.47	5.23	4.78	4.32	3.96	3.65	3.14	2.76	2.22	1.84	0.85	0.54	0.31	1.17	182.1	219.7	4.43	1.56	1.05
.078	7.19	6.51	6.25	5.98	5.76	5.53	5.29	4.83	4.37	4.00	3.69	3.18	2.80	2.25	1.88	0.87	0.55	0.31	1.18	185.1	223.6	4.48	1.55	1.07
.080	7.28	6.58	6.32	6.04	5.82	5.59	5.35	4.88	4.42	4.05	3.73	3.23	2.83	2.27	1.90	0.89	0.56	0.32	1.19	188.2	227.4	4.53	1.55	1.10

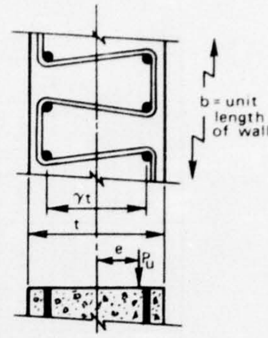
p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	VALUES OF ECCENTRICITY RATIO $\delta e/t$																							
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	4.32	3.94	3.80	3.65	3.50	3.36	3.22	2.90	2.60	2.33	2.07	1.65	1.26	0.72	0.48	0.18	0.11	0.06	1.00	93.7	64.6	3.13	1.96	0.23
.012	4.41	4.02	3.87	3.72	3.57	3.43	3.29	2.96	2.66	2.41	2.15	1.74	1.36	0.81	0.55	0.21	0.13	0.07	1.00	99.1	74.8	3.18	1.95	0.26
.014	4.49	4.09	3.94	3.79	3.64	3.50	3.36	3.03	2.72	2.48	2.22	1.82	1.44	0.89	0.62	0.23	0.14	0.08	1.00	104.5	84.6	3.22	1.95	0.29
.016	4.57	4.17	4.02	3.86	3.71	3.57	3.42	3.09	2.78	2.54	2.29	1.87	1.54	0.98	0.68	0.26	0.16	0.09	1.00	109.9	93.9	3.27	1.94	0.33
.018	4.65	4.24	4.09	3.93	3.77	3.63	3.49	3.15	2.84	2.60	2.36	1.92	1.62	1.05	0.74	0.28	0.17	0.10	1.00	115.3	103.0	3.32	1.94	0.36
.020	4.74	4.32	4.16	4.00	3.84	3.70	3.55	3.22	2.90	2.66	2.43	1.98	1.70	1.14	0.80	0.31	0.19	0.11	1.00	120.7	111.8	3.37	1.93	0.39
.022	4.82	4.39	4.23	4.07	3.91	3.76	3.62	3.28	2.97	2.72	2.49	2.05	1.77	1.22	0.86	0.33	0.20	0.12	1.00	126.1	120.3	3.42	1.93	0.43
.024	4.90	4.47	4.31	4.14	3.98	3.83	3.68	3.34	3.03	2.78	2.56	2.12	1.81	1.29	0.90	0.36	0.22	0.12	1.00	131.5	128.6	3.46	1.93	0.46
.026	4.98	4.54	4.38	4.21	4.04	3.90	3.75	3.40	3.09	2.83	2.58	2.18	1.85	1.35	0.97	0.38	0.23	0.13	1.01	136.9	136.7	3.51	1.92	0.49
.028	5.07	4.62	4.45	4.28	4.11	3.96	3.81	3.46	3.15	2.88	2.63	2.24	1.88	1.41	1.02	0.40	0.25	0.14	1.03	142.3	144.6	3.56	1.92	0.52
.030	5.15	4.69	4.52	4.35	4.18	4.03	3.88	3.52	3.21	2.94	2.69	2.29	1.91	1.48	1.08	0.43	0.26	0.15	1.05	147.7	152.4	3.61	1.91	0.55
.032	5.23	4.77	4.60	4.42	4.25	4.09	3.94	3.58	3.27	2.99	2.74	2.35	1.98	1.54	1.14	0.45	0.28	0.16	1.07	153.1	160.0	3.65	1.91	0.58
.034	5.32	4.84	4.67	4.49	4.31	4.16	4.00	3.63	3.33	3.03	2.79	2.41	2.04	1.60	1.19	0.47	0.29	0.17	1.09	158.5	167.5	3.70	1.90	0.61
.036	5.40	4.92	4.74	4.56	4.38	4.22	4.07	3.69	3.39	3.08	2.84	2.47	2.10	1.65	1.25	0.50	0.31	0.18	1.11	163.9	174.8	3.75	1.90	0.65
.038	5.49	5.00	4.81	4.63	4.45	4.29	4.13	3.75	3.45	3.13	2.90	2.49	2.15	1.70	1.30	0.52	0.32	0.18	1.13	169.3	182.1	3.80	1.90	0.68
.040	5.57	5.07	4.89	4.70	4.52	4.35	4.20	3.81	3.51	3.19	2.95	2.54	2.20	1.74	1.36	0.54	0.34	0.19	1.14	174.7	189.2	3.85	1.89	0.71
.042	5.65	5.15	4.96	4.77	4.59	4.42	4.26	3.86	3.56	3.24	3.00	2.59	2.25	1.76	1.39	0.57	0.35	0.20	1.16	180.1	196.3	3.89	1.89	0.74
.044	5.74	5.22	5.03	4.84	4.65	4.48	4.33	3.92	3.62	3.30	3.05	2.63	2.30	1.79	1.45	0.59	0.37	0.21	1.18	185.5	203.2	3.94	1.88	0.77
.046	5.82	5.30	5.10	4.91	4.72	4.55	4.39	3.98	3.68	3.36	3.13	2.68	2.35	1.81	1.50	0.61	0.38	0.22	1.20	190.9	210.1	3.99	1.88	0.80
.048	5.91	5.37	5.18	4.98	4.79	4.61	4.45	4.04	3.73	3.42	3.18	2.73	2.39	1.83	1.54	0.64	0.40	0.23	1.21	196.3	216.9	4.04	1.87	0.83
.050	5.99	5.45	5.25	5.06	4.86	4.68	4.52	4.09	3.79	3.47	3.23	2.77	2.44	1.85	1.58	0.66	0.41	0.23	1.23	201.7	223.7	4.08	1.87	0.86
.052	6.08	5.52	5.32	5.13	4.92	4.74	4.58	4.15	3.85	3.53	3.27	2.82	2.49	1.86	1.62	0.69	0.43	0.24	1.25	207.1	230.3	4.13	1.87	0.90
.054	6.16	5.60	5.39	5.20	4.99	4.81	4.64	4.21	3.90	3.58	3.32	2.87	2.54	1.91	1.66	0.71	0.44	0.25	1.26	212.5	236.9	4.18	1.86	0.93
.056	6.24	5.67	5.46	5.27	5.06	4.87	4.71	4.27	3.96	3.64	3.36	2.91	2.56	1.96	1.69	0.73	0.46	0.26	1.28	217.9	243.5	4.23	1.86	0.96
.058	6.33	5.75	5.54	5.34	5.13	4.94	4.77	4.33	4.01	3.69	3.40	2.96	2.60	2.01	1.71	0.75	0.47	0.27	1.29	223.3	249.9	4.27	1.85	0.99
.060	6.41	5.82	5.61	5.41	5.20	5.00	4.83	4.39	4.07	3.75	3.45	3.00	2.64	2.06	1.73	0.78	0.48	0.28	1.31	228.7	256.4	4.32	1.85	1.02
.062	6.50	5.90	5.68	5.48	5.26	5.06	4.90	4.45	4.12	3.80	3.49	3.05	2.68	2.10	1.75	0.80	0.50	0.28	1.32	234.1	262.8	4.37	1.84	1.05
.064	6.58	5.98	5.75	5.55	5.33	5.13	4.96	4.51	4.18	3.86	3.53	3.09	2.72	2.15	1.76	0.82	0.51	0.29	1.34	239.5	269.1	4.42	1.84	1.08
.066	6.67	6.05	5.83	5.62	5.40	5.19	5.02	4.57	4.23	3.91	3.58	3.14	2.76	2.19	1.77	0.85	0.53	0.30	1.36	244.9	275.4	4.47	1.84	1.11
.068	6.75	6.13	5.90	5.69	5.47	5.26	5.09	4.63	4.29	3.97	3.63	3.18	2.81	2.24	1.79	0.87	0.54	0.31	1.37	250.3	281.6	4.51	1.83	1.14
.070	6.84	6.20	5.97	5.76	5.53	5.32	5.15	4.69	4.34	4.02	3.68	3.23	2.85	2.28	1.80	0.90	0.56	0.32	1.38	255.7	287.8	4.56	1.83	1.18
.072	6.92	6.28	6.04	5.83	5.60	5.39	5.21	4.75	4.40	4.02	3.73	3.27	2.89	2.32	1.81	0.92	0.57	0.33	1.40	261.1	294.0	4.61	1.82	1.21
.074	7.00	6.35	6.12	5.90	5.67	5.45	5.27	4.81	4.45	4.07	3.79	3.32	2.93	2.35	1.82	0.94	0.59	0.33	1.41	266.5	300.1	4.66	1.82	1.24
.076	7.09	6.43	6.19	5.97	5.74	5.51	5.34	4.87	4.50	4.12	3.84	3.36	2.97	2.39	1.85	0.97	0.60	0.34	1.43	271.9	306.2	4.70	1.81	1.27
.078	7.17	6.50	6.26	6.04	5.81	5.58	5.40	4.93	4.56	4.17	3.89	3.40	3.01	2.43	1.90	0.99	0.62	0.35	1.44	277.3	312.3	4.75	1.81	1.30
.080	7.26	6.58	6.33	6.11	5.87	5.64	5.46	4.99	4.61	4.22	3.94	3.45	3.05	2.46	1.94	1.01	0.63	0.36	1.46	282.7	318.3	4.80	1.81	1.33

L/t_e	VALUES OF MOMENT MULTIPLIERS δ — VALUES OF ULTIMATE STRESS P_u/A_g IN KSI																					
	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03
3.0	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.04	1.04	1.05	1.05	1.06	1.06
4.0	1.00	1.00	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.06	1.07	1.08	1.09	1.10	1.11	1.12
5.0	1.00	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.04	1.04	1.04	1.05	1.05	1.06	1.06	1.10	1.11	1.13	1.15	1.16	1.18	1.20
6.0	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.08	1.09	1.15	1.17	1.20	1.22	1.25	1.28	1.31
7.0	1.01	1.02	1.02	1.03	1.04	1.05	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.21	1.25	1.29	1.33	1.38	1.42	1.48
8.0	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.10	1.11	1.12	1.13	1.14	1.16	1.17	1.29	1.35	1.41	1.48	1.55	1.64	1.73
9.0	1.01	1.03	1.04	1.05	1.07	1.08	1.09	1.11	1.12	1.14	1.16	1.17	1.19	1.21	1.23	1.40	1.49	1.59	1.70	1.82	1.97	2.14
10.0	1.02	1.03	1.05	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.25	1.27	1.30	1.55	1.68	1.84	2.03	2.26	2.55	2.93
11.0	1.02	1.04	1.06	1.08	1.10	1.12	1.15	1.17	1.20	1.23	1.25	1.28	1.31	1.35	1.38	1.75	1.96	2.23	2.58	3.07	3.78	4.92
12.0	1.02	1.05	1.07	1.10	1.12	1.15	1.18	1.21	1.25	1.28	1.32	1.36	1.40	1.44	1.49	2.04	2.40	2.91	3.70	5.06	8.03	
13.0	1.03	1.05	1.08	1.11	1.15	1.18	1.22	1.26	1.30	1.35	1.39	1.45	1.50	1.56	1.63	2.50	3.17	4.36	6.95			
14.0	1.03	1.06	1.10	1.14	1.18	1.22	1.26	1.31	1.37	1.42	1.49	1.56	1.63	1.72	1.81	3.28	4.86	9.40				
15.0	1.04	1.07	1.11	1.16	1.21	1.26	1.31	1.38	1.44	1.52	1.60	1.70	1.80	1.92	2.05	4.95						
16.0	1.04	1.08	1.13	1.18	1.24	1.30	1.37	1.45	1.54	1.64	1.75	1.88	2.02	2.20	2.40							
17.0	1.05	1.10	1.15	1.21	1.28	1.36	1.44	1.54	1.65	1.78	1.93	2.11	2.33	2.60	2.93							
18.0	1.05	1.11	1.17	1.25	1.33	1.42	1.53	1.65	1.80	1.97	2.18	2.44	2.78	3.22	3.83							

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .75$ — VALUES OF ECCENTRICITY RATIO $\delta e/t$																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	4.30	3.90	3.75	3.60	3.45	3.31	3.17	2.85	2.55	2.31	2.05	1.57	1.19	0.69	0.46	0.17	0.10	0.06	1.00	108.9	79.6	3.40	2.14	0.23
.012	4.38	3.98	3.83	3.67	3.52	3.38	3.24	2.92	2.62	2.39	2.15	1.69	1.31	0.80	0.53	0.19	0.12	0.07	1.00	117.3	92.8	3.45	2.14	0.27
.014	4.47	4.06	3.90	3.75	3.59	3.46	3.32	3.00	2.70	2.47	2.25	1.79	1.41	0.90	0.61	0.22	0.14	0.08	1.00	125.7	105.5	3.50	2.13	0.31
.016	4.55	4.14	3.98	3.83	3.67	3.53	3.39	3.07	2.77	2.54	2.33	1.89	1.51	0.99	0.68	0.25	0.15	0.09	1.00	134.2	117.8	3.54	2.13	0.34
.018	4.64	4.22	4.06	3.90	3.74	3.60	3.46	3.13	2.85	2.61	2.40	1.98	1.61	1.07	0.76	0.28	0.17	0.10	1.03	142.6	129.8	3.59	2.12	0.38
.020	4.73	4.29	4.13	3.98	3.82	3.67	3.53	3.20	2.92	2.67	2.44	2.06	1.70	1.16	0.83	0.31	0.19	0.11	1.06	151.0	141.5	3.64	2.12	0.42
.022	4.82	4.37	4.21	4.05	3.89	3.74	3.61	3.27	2.99	2.72	2.50	2.15	1.78	1.24	0.90	0.34	0.21	0.12	1.09	159.5	153.0	3.69	2.11	0.46
.024	4.90	4.45	4.28	4.12	3.96	3.81	3.68	3.33	3.06	2.78	2.60	2.22	1.86	1.31	0.96	0.36	0.22	0.13	1.12	167.9	164.2	3.73	2.11	0.50
.026	4.99	4.53	4.36	4.20	4.04	3.88	3.74	3.39	3.13	2.85	2.66	2.26	1.94	1.38	1.02	0.39	0.24	0.14	1.15	176.4	175.2	3.78	2.11	0.54
.028	5.08	4.61	4.43	4.27	4.11	3.95	3.81	3.46	3.19	2.92	2.71	2.32	2.01	1.45	1.08	0.42	0.26	0.14	1.18	184.8	186.0	3.83	2.10	0.58
.030	5.16	4.69	4.51	4.35	4.18	4.02	3.88	3.53	3.25	2.99	2.76	2.38	2.07	1.52	1.13	0.45	0.27	0.15	1.20	193.2	196.7	3.88	2.10	0.62
.032	5.25	4.76	4.58	4.42	4.26	4.09	3.95	3.60	3.32	3.05	2.81	2.43	2.14	1.59	1.19	0.48	0.29	0.16	1.23	201.7	207.2	3.92	2.09	0.66
.034	5.34	4.84	4.66	4.49	4.33	4.16	4.02	3.67	3.38	3.12	2.86	2.49	2.19	1.65	1.25	0.50	0.31	0.17	1.26	210.1	217.6	3.97	2.09	0.70
.036	5.43	4.92	4.73	4.57	4.40	4.23	4.08	3.74	3.44	3.18	2.91	2.54	2.24	1.70	1.31	0.53	0.33	0.18	1.28	218.5	227.8	4.02	2.09	0.73
.038	5.51	5.00	4.81	4.64	4.47	4.30	4.15	3.80	3.50	3.24	2.98	2.60	2.29	1.76	1.36	0.56	0.34	0.19	1.30	227.0	238.0	4.07	2.08	0.77
.040	5.60	5.08	4.88	4.71	4.54	4.37	4.22	3.87	3.55	3.30	3.04	2.65	2.34	1.82	1.42	0.59	0.36	0.20	1.33	235.4	248.0	4.12	2.08	0.81
.042	5.69	5.15	4.96	4.79	4.62	4.44	4.28	3.94	3.61	3.36	3.11	2.70	2.39	1.88	1.47	0.62	0.38	0.21	1.35	243.9	257.9	4.16	2.07	0.85
.044	5.77	5.23	5.03	4.86	4.69	4.51	4.35	4.00	3.67	3.42	3.17	2.75	2.43	1.93	1.53	0.64	0.39	0.22	1.38	252.3	267.8	4.21	2.07	0.89
.046	5.86	5.31	5.11	4.93	4.76	4.58	4.41	4.07	3.72	3.48	3.23	2.80	2.48	1.98	1.58	0.67	0.41	0.23	1.40	260.7	277.5	4.26	2.06	0.93
.048	5.95	5.39	5.19	5.00	4.83	4.65	4.47	4.13	3.78	3.54	3.24	2.85	2.53	2.03	1.62	0.70	0.43	0.24	1.42	269.2	287.2	4.31	2.06	0.97
.050	6.03	5.46	5.26	5.07	4.90	4.72	4.54	4.20	3.83	3.59	3.30	2.89	2.58	2.09	1.67	0.73	0.45	0.25	1.44	277.6	296.8	4.35	2.06	1.01
.052	6.12	5.54	5.34	5.15	4.97	4.79	4.61	4.26	3.90	3.65	3.35	2.94	2.63	2.12	1.71	0.76	0.46	0.26	1.46	286.0	306.3	4.40	2.05	1.05
.054	6.21	5.62	5.41	5.22	5.04	4.86	4.68	4.32	3.96	3.70	3.41	3.01	2.67	2.16	1.76	0.78	0.48	0.27	1.49	294.5	315.8	4.45	2.05	1.08
.056	6.29	5.70	5.49	5.29	5.11	4.93	4.75	4.39	4.02	3.76	3.46	3.05	2.70	2.20	1.80	0.81	0.50	0.28	1.51	302.9	325.2	4.50	2.04	1.12
.058	6.38	5.78	5.56	5.36	5.18	5.00	4.82	4.45	4.09	3.81	3.51	3.09	2.74	2.24	1.85	0.84	0.52	0.29	1.53	311.4	334.5	4.55	2.04	1.16
.060	6.46	5.85	5.64	5.43	5.25	5.07	4.89	4.51	4.15	3.87	3.57	3.12	2.79	2.28	1.89	0.86	0.53	0.30	1.55	319.8	343.8	4.59	2.03	1.20
.062	6.55	5.93	5.72	5.50	5.32	5.14	4.95	4.57	4.21	3.92	3.62	3.18	2.83	2.32	1.92	0.89	0.55	0.31	1.57	328.2	353.1	4.64	2.03	1.24
.064	6.64	6.01	5.79	5.57	5.39	5.21	5.02	4.64	4.27	3.97	3.67	3.23	2.87	2.36	1.96	0.91	0.57	0.32	1.59	336.7	362.3	4.69	2.03	1.28
.066	6.72	6.08	5.87	5.64	5.46	5.28	5.09	4.70	4.33	4.02	3.73	3.29	2.92	2.39	2.00	0.94	0.58	0.33	1.61	345.1	371.4	4.74	2.02	1.32
.068	6.81	6.16	5.94	5.72	5.53	5.35	5.16	4.76	4.40	4.07	3.78	3.34	2.96	2.42	2.05	0.96	0.60	0.34	1.63	353.5	380.5	4.78	2.02	1.36
.070	6.89	6.24	6.02	5.79	5.60	5.42	5.23	4.82	4.46	4.12	3.83	3.36	3.02	2.46	2.08	0.99	0.62	0.35	1.65	362.0	389.6	4.83	2.01	1.40
.072	6.98	6.32	6.09	5.86	5.67	5.49	5.29	4.88	4.52	4.18	3.89	3.41	3.07	2.50	2.11	1.01	0.64	0.36	1.67	370.4	398.6	4.88	2.01	1.43
.074	7.07	6.39	6.17	5.93	5.74	5.56	5.36	4.94	4.58	4.23	3.94	3.45	3.11	2.54	2.15	1.04	0.65	0.37	1.69	378.9	407.6	4.93	2.00	1.47
.076	7.15	6.47	6.24	6.01	5.81	5.62	5.43	5.01	4.64	4.28	3.99	3.50	3.15	2.57	2.18	1.06	0.67	0.38	1.70	387.3	416.6	4.98	2.00	1.51
.078	7.24	6.55	6.32	6.08	5.88	5.69	5.50	5.07	4.70	4.33	4.04	3.55	3.19	2.61	2.22	1.09	0.69	0.39	1.72	395.7	425.5	5.02	2.00	1.55
.080	7.32	6.62	6.39	6.15	5.95	5.76	5.56	5.13	4.76	4.38	4.09	3.60	3.23	2.65	2.25	1.11	0.70	0.40	1.74	404.2	434.4	5.07	1.99	1.59

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .9$ — VALUES OF ECCENTRICITY RATIO $\delta e/t$																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	4.29	3.87	3.72	3.56	3.41	3.27	3.13	2.82	2.51	2.24	1.99	1.51	1.14	0.69	0.46	0.17	0.10	0.06	1.00	127.4	97.8	3.67	2.33	0.24
.012	4.38	3.96	3.80	3.65	3.49	3.36	3.22	2.90	2.61	2.32	2.11	1.64	1.27	0.79	0.55	0.20	0.12	0.07	1.02	139.6	114.6	3.72	2.32	0.29
.014	4.47	4.04	3.88	3.73	3.57	3.44	3.30	2.98	2.70	2.43	2.20	1.75	1.38	0.89	0.63	0.23	0.14	0.08	1.07	151.7	130.9	3.77	2.32	0.33
.016	4.56	4.13	3.96	3.81	3.66	3.51	3.38	3.06	2.79	2.52	2.27	1.87	1.49	1.00	0.70	0.26	0.16	0.09	1.11	163.9	146.8	3.81	2.31	0.38
.018	4.66	4.21	4.04	3.89	3.74	3.59	3.46	3.13	2.87	2.61	2.35	1.97	1.60	1.08	0.77	0.29	0.18	0.10	1.15	176.0	162.3	3.86	2.31	0.43
.020	4.75	4.29	4.12	3.97	3.82	3.66	3.54	3.21	2.95	2.69	2.44	2.07	1.70	1.17	0.85	0.32	0.20	0.11	1.19	188.2	177.5	3.91	2.30	0.47
.022	4.84	4.37	4.20	4.05	3.90	3.74	3.61	3.29	3.02	2.77	2.52	2.15	1.78	1.26	0.92	0.36	0.22	0.13	1.23	200.3	192.5	3.96	2.30	0.52
.024	4.93	4.46	4.28	4.13	3.98	3.82	3.68	3.36	3.09	2.85	2.60	2.20	1.88	1.33	0.98	0.39	0.24	0.13	1.26	212.5	207.3	4.00	2.30	0.57
.026	5.02	4.54	4.36	4.21	4.05	3.90	3.75	3.44	3.15	2.92	2.68	2.25	1.96	1.40	1.05	0.42	0.26	0.14	1.30	224.6	221.8	4.05	2.29	0.61
.028	5.11	4.62	4.44	4.28	4.13	3.98	3.82	3.51	3.22	2.99	2.76	2.30	2.04	1.48	1.11	0.45	0.28	0.15	1.33	236.8	236.2	4.10	2.29	0.66
.030	5.21	4.70	4.52	4.36	4.21	4.05	3.90	3.59	3.28	3.06	2.83	2.38	2.11	1.56	1.17	0.48	0.29	0.16	1.37	248.9	250.4	4.15	2.28	0.71
.032	5.30	4.78	4.60	4.43	4.28	4.13	3.97	3.66	3.34	3.12	2.90	2.46	2.16	1.63	1.23	0.51	0.31	0.18	1.40	261.1	264.4	4.20	2.28	0.75
.034	5.38	4.86	4.68	4.51	4.36	4.20	4.05	3.73	3.42	3.18	2.93	2.53	2.20	1.69	1.31	0.54	0.33	0.19	1.43	273.2	278.3	4.24	2.27	0.80
.036	5.47	4.94	4.76	4.58	4.43	4.28	4.12	3.80	3.49	3.24	2.99	2.60	2.23	1.75	1.35	0.57	0.35	0.20	1.46	285.4	292.1	4.29	2.27	0.85
.038	5.56	5.02	4.84	4.66	4.50	4.35	4.20	3.86	3.56	3.30	3.05	2.66	2.26	1.82	1.41	0.60	0.37	0.21	1.49	297.5	305.8	4.34	2.27	0.89
.040	5.64	5.10	4.92	4.74	4.58	4.43	4.27	3.93	3.63	3.36	3.11	2.73	2.34	1.89	1.48	0.63	0.39	0.22	1.52	309.7	319.3	4.39	2.26	0.94
.042	5.72	5.18	5.00	4.82	4.65	4.50	4.34	4.00	3.70	3.41	3.17	2.80	2.41	1.95	1.53	0.66	0.41	0.23	1.55	321.8	332.7	4.43	2.26	0.99
.044	5.79	5.26	5.08	4.89	4.72	4.57	4.42	4.06	3.76	3.46	3.23	2.83	2.47	2.01	1.59	0.69	0.43	0.24	1.58	334.0	346.1	4.48	2.25	1.03
.046	5.87	5.34	5.16	4.97	4.79	4.64	4.49	4.12	3.83	3.52	3.29	2.88	2.53	2.06	1.64	0.72	0.45	0.25	1.61	346.1	359.3	4.53	2.25	1.08
.048	5.95	5.42	5.23	5.05	4.87	4.71	4.56	4.19	3.90	3.59	3.38	2.94	2.60	2.09	1.68	0.75	0.47	0.26	1.64	358.3	372.5	4.58	2.25	1.13
.050	6.02	5.49	5.31	5.12	4.94	4.79	4.63	4.25	3.96	3.66	3.43	2.99	2.65	2.12	1.73	0.78	0.48	0.27	1.67	370.4	385.6	4.63	2.24	1.17
.052	6.10	5.57	5.39	5.20	5.01	4.86	4.70	4.31	4.02	3.72	3.49	3.05	2.71	2.15	1.79	0.80	0.50	0.28	1.69	382.6	398.7	4.67	2.24	1.22
.054	6.18	5.65	5.47	5.28	5.08	4.93	4.77	4.37	4.09	3.79	3.54	3.10	2.77	2.17	1.84	0.83	0.52	0.29	1.72	394.7	411.6	4.72	2.23	1.27
.056	6.26	5.73	5.54	5.35	5.16	5.00	4.84	4.44	4.15	3.85	3.59	3.15	2.83	2.19	1.89	0.86	0.54	0.31	1.75	406.9	424.5	4.77	2.23	1.31
.058	6.35	5.81	5.62	5.43	5.23	5.07	4.91	4.51	4.21	3.92	3.63	3.21	2.85	2.21	1.94	0.89	0.56	0.32	1.77	419.0	437.4	4.82	2.22	1.36
.060	6.44	5.89	5.70	5.50	5.31	5.14	4.98	4.58	4.27	3.98	3.68	3.26	2.90	2.26	1.98	0.92	0.58	0.33	1.80	431.2	450.2	4.86	2.22	1.41
.062	6.53	5.97	5.77	5.58	5.38	5.20	5.05	4.65	4.33	4.04	3.73	3.31	2.95	2.32	2.03	0.95	0.59	0.34	1.82	443.3	462.9	4.91	2.22	1.46
.064	6.61	6.05	5.85	5.66	5.46	5.27	5.12	4.72	4.39	4.10	3.80	3.36	3.00	2.37	2.05	0.97	0.61	0.35	1.85	455.5	475.6	4.96	2.21	1.50
.066	6.70	6.14	5.92	5.73	5.53	5.34	5.19	4.78	4.45	4.16	3.86	3.41	3.05	2.43	2.07	1.00	0.63	0.36	1.87	467.6	488.2	5.01	2.21	1.55
.068	6.79	6.22	6.00	5.81	5.61	5.41	5.25	4.85	4.51	4.22	3.92	3.46	3.09	2.48	2.09	1.03	0.65	0.37	1.90	479.8	500.8	5.06	2.20	1.60
.070	6.87	6.30	6.08	5.88	5.68	5.48	5.32	4.92	4.57	4.28	3.98	3.51	3.14	2.54	2.11	1.06	0.67	0.38	1.92	491.9	513.4	5.10	2.20	1.64
.072	6.96	6.38	6.15	5.96	5.75	5.55	5.39	4.99	4.63	4.34	4.04	3.56	3.19	2.59	2.13	1.08	0.69	0.39	1.94	504.1	525.9	5.15	2.19	1.69
.074	7.05	6.47	6.23	6.03	5.83	5.62	5.46	5.05	4.69	4.40	4.10	3.61	3.24	2.64	2.14	1.11	0.70	0.40	1.97	516.2	538.4	5.20	2.19	1.74
.076	7.13	6.55	6.30	6.10	5.90	5.69	5.52	5.12	4.74	4.41	4.16	3.66	3.28	2.68	2.16	1.14	0.72	0.41	1.99	528.4	550.8	5.25	2.19	1.78
.078	7.22	6.63	6.38	6.18	5.98	5.77	5.59	5.19	4.80	4.47	4.22	3.71	3.33	2.73	2.17	1.17	0.74	0.42	2.01	540.5	563.2	5.29	2.18	1.83
.080	7.31	6.71	6.45	6.25	6.05	5.84	5.66	5.25	4.86	4.58	4.23	3.76	3.38	2.77	2.19	1.19	0.76	0.43	2.04	552.7	575.6	5.34	2.18	.88

Table 6.6A.3 Values of ultimate axial stress, P_u/A_g, for rectangular column with symmetric reinforcing steel, f'_c = 5 ksi, f_{dy} = 52 ksi, γ = 0.45, 0.60, 0.75, 0.90



VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .45

P_g Steel Ratio	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. t Ratio t_e/t	EI_b/bt^3	EI_t/bt^3	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	M_u/bt^2
	VALUES OF ECCENTRICITY RATIO $\delta e/t$																							
.010	5.35	4.91	4.74	4.57	4.40	4.22	4.06	3.64	3.25	2.90	2.58	2.04	1.52	0.89	0.59	0.22	0.13	0.07	1.00	98.5	55.3	3.31	2.07	0.26
.012	5.43	4.99	4.81	4.63	4.46	4.28	4.11	3.69	3.30	2.96	2.64	2.12	1.60	0.97	0.66	0.25	0.15	0.08	1.00	101.6	63.8	3.36	2.06	0.29
.014	5.52	5.06	4.88	4.70	4.52	4.34	4.17	3.74	3.35	3.01	2.68	2.20	1.70	1.03	0.72	0.27	0.17	0.10	1.00	104.6	71.8	3.41	2.06	0.32
.016	5.60	5.14	4.95	4.77	4.58	4.40	4.23	3.80	3.40	3.06	2.73	2.27	1.79	1.11	0.77	0.30	0.18	0.10	1.00	107.6	79.5	3.45	2.05	0.35
.018	5.68	5.21	5.02	4.83	4.65	4.46	4.28	3.85	3.45	3.11	2.77	2.29	1.86	1.17	0.83	0.32	0.20	0.11	1.00	110.7	86.8	3.50	2.04	0.38
.020	5.77	5.28	5.09	4.90	4.71	4.52	4.34	3.90	3.50	3.16	2.83	2.34	1.93	1.24	0.87	0.34	0.21	0.12	1.00	113.7	93.9	3.55	2.04	0.41
.022	5.85	5.36	5.16	4.97	4.77	4.58	4.40	3.95	3.55	3.21	2.88	2.39	1.99	1.30	0.92	0.36	0.23	0.13	1.00	116.7	100.6	3.59	2.03	0.43
.024	5.93	5.43	5.23	5.03	4.83	4.64	4.46	4.00	3.60	3.26	2.93	2.44	2.06	1.37	0.97	0.38	0.24	0.14	1.00	119.8	107.2	3.64	2.02	0.46
.026	6.02	5.50	5.30	5.10	4.90	4.70	4.51	4.06	3.65	3.31	2.98	2.49	2.13	1.41	1.02	0.40	0.25	0.14	1.00	122.8	113.5	3.69	2.01	0.48
.028	6.10	5.58	5.37	5.16	4.96	4.76	4.57	4.11	3.70	3.36	3.03	2.53	2.16	1.49	1.07	0.43	0.27	0.15	1.00	125.9	119.7	3.73	2.01	0.51
.030	6.18	5.65	5.43	5.23	5.02	4.82	4.63	4.16	3.74	3.40	3.08	2.58	2.20	1.53	1.11	0.45	0.28	0.16	1.00	128.9	125.7	3.78	2.00	0.54
.032	6.27	5.72	5.50	5.30	5.08	4.88	4.68	4.21	3.79	3.45	3.13	2.62	2.25	1.59	1.16	0.47	0.29	0.17	1.00	131.9	131.5	3.83	1.99	0.56
.034	6.35	5.80	5.57	5.36	5.15	4.94	4.74	4.26	3.84	3.50	3.18	2.67	2.29	1.65	1.21	0.49	0.30	0.17	1.00	135.0	137.2	3.87	1.98	0.59
.036	6.43	5.87	5.64	5.43	5.21	5.00	4.80	4.32	3.89	3.55	3.23	2.71	2.33	1.71	1.25	0.51	0.32	0.18	1.00	138.0	142.8	3.92	1.98	0.61
.038	6.52	5.94	5.71	5.49	5.27	5.06	4.86	4.37	3.94	3.59	3.28	2.75	2.38	1.76	1.28	0.53	0.33	0.19	1.00	141.0	148.2	3.97	1.97	0.64
.040	6.60	6.01	5.78	5.56	5.33	5.11	4.91	4.42	3.99	3.64	3.33	2.80	2.42	1.83	1.33	0.55	0.34	0.20	1.00	144.1	153.6	4.02	1.96	0.66
.042	6.68	6.09	5.85	5.62	5.39	5.17	4.97	4.47	4.04	3.69	3.37	2.84	2.46	1.87	1.37	0.57	0.35	0.20	1.00	147.1	158.8	4.06	1.96	0.68
044	6.77	6.16	5.92	5.69	5.46	5.23	5.03	4.53	4.09	3.73	3.42	2.88	2.50	1.90	1.42	0.59	0.37	0.21	1.00	150.2	163.9	4.11	1.95	0.71
.046	6.85	6.23	5.99	5.76	5.52	5.29	5.08	4.58	4.14	3.78	3.41	2.92	2.52	1.93	1.47	0.61	0.38	0.22	1.00	153.2	169.0	4.16	1.94	0.73
.048	6.93	6.31	6.06	5.82	5.58	5.35	5.14	4.63	4.19	3.82	3.46	2.96	2.55	1.98	1.50	0.63	0.39	0.22	1.00	156.2	173.9	4.20	1.93	0.76
.050	7.01	6.38	6.13	5.89	5.64	5.41	5.20	4.68	4.24	3.87	3.50	3.00	2.59	2.05	1.54	0.65	0.40	0.23	1.00	159.3	178.8	4.25	1.93	0.78
.052	7.10	6.45	6.19	5.95	5.70	5.47	5.26	4.74	4.28	3.92	3.55	3.03	2.63	2.06	1.59	0.66	0.42	0.24	1.00	162.3	183.6	4.30	1.92	0.81
054	7.18	6.52	6.26	6.02	5.76	5.53	5.31	4.79	4.33	3.96	3.59	3.07	2.67	2.10	1.63	0.68	0.43	0.24	1.00	165.3	188.3	4.34	1.91	0.83
.056	7.26	6.59	6.33	6.08	5.82	5.59	5.37	4.84	4.38	4.01	3.63	3.11	2.70	2.14	1.67	0.70	0.44	0.25	1.01	168.4	192.9	4.39	1.91	0.85
.058	7.35	6.67	6.40	6.15	5.89	5.65	5.43	4.89	4.43	4.05	3.68	3.17	2.74	2.18	1.71	0.72	0.45	0.26	1.01	171.4	197.5	4.44	1.90	0.88
.060	7.43	6.74	6.47	6.21	5.95	5.71	5.48	4.95	4.48	4.10	3.72	3.20	2.78	2.21	1.76	0.74	0.46	0.27	1.02	174.5	202.1	4.48	1.89	0.90
.062	7.51	6.81	6.54	6.28	6.01	5.77	5.54	5.00	4.53	4.14	3.76	3.24	2.81	2.23	1.80	0.76	0.48	0.27	1.03	177.5	206.5	4.53	1.88	0.92
.064	7.59	6.88	6.61	6.34	6.07	5.83	5.60	5.05	4.58	4.19	3.81	3.27	2.85	2.26	1.83	0.77	0.49	0.28	1.04	180.5	210.9	4.58	1.88	0.95
.066	7.68	6.96	6.68	6.41	6.13	5.89	5.65	5.10	4.63	4.23	3.85	3.30	2.89	2.29	1.85	0.80	0.50	0.29	1.05	183.6	215.3	4.62	1.87	0.97
068	7.76	7.03	6.75	6.47	6.19	5.95	5.71	5.16	4.68	4.28	3.89	3.33	2.92	2.32	1.87	0.81	0.51	0.29	1.06	186.6	219.6	4.67	1.86	1.00
.070	7.84	7.10	6.82	6.54	6.25	6.01	5.77	5.21	4.73	4.32	3.94	3.36	2.96	2.35	1.91	0.83	0.52	0.30	1.07	189.6	223.9	4.72	1.85	1.02
.072	7.92	7.17	6.88	6.60	6.31	6.07	5.83	5.26	4.78	4.37	3.98	3.39	2.99	2.38	1.95	0.85	0.54	0.31	1.08	192.7	228.1	4.76	1.85	1.04
.074	8.01	7.24	6.95	6.67	6.37	6.13	5.88	5.32	4.82	4.41	4.02	3.44	3.03	2.41	1.98	0.87	0.55	0.31	1.08	195.7	232.3	4.81	1.84	1.07
.076	8.09	7.31	7.02	6.73	6.44	6.19	5.94	5.37	4.87	4.46	4.06	3.48	3.07	2.44	2.01	0.89	0.56	0.32	1.09	198.8	236.5	4.86	1.83	1.09
.078	8.17	7.39	7.09	6.80	6.50	6.25	6.00	5.42	4.92	4.50	4.11	3.52	3.10	2.47	2.04	0.91	0.57	0.33	1.10	201.8	240.6	4.90	1.83	1.11
.080	8.25	7.46	7.16	6.86	6.56	6.31	6.05	5.47	4.97	4.55	4.15	3.57	3.14	2.50	2.07	0.92	0.58	0.33	1.11	204.8	244.6	4.95	1.82	1.14

VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6

P_g Steel Ratio	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. t Ratio t_e/t	EI_b/bt^3	EI_t/bt^3	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	M_u/bt^2
	VALUES OF ECCENTRICITY RATIO $\delta e/t$																							
.010	5.30	4.83	4.65	4.47	4.28	4.10	3.93	3.52	3.12	2.80	2.47	1.92	1.42	0.78	0.51	0.19	0.12	0.06	1.00	110.3	67.3	3.63	2.30	0.24
.012	5.38	4.91	4.72	4.53	4.35	4.17	4.00	3.58	3.19	2.87	2.55	2.02	1.55	0.87	0.58	0.22	0.13	0.08	1.00	115.7	78.1	3.68	2.29	0.27
.014	5.46	4.98	4.79	4.60	4.42	4.23	4.06	3.64	3.25	2.94	2.62	2.11	1.63	0.97	0.65	0.24	0.15	0.08	1.00	121.1	88.5	3.73	2.29	0.31
.016	5.55	5.06	4.86	4.67	4.48	4.30	4.12	3.70	3.32	3.00	2.70	2.18	1.73	1.06	0.72	0.27	0.16	0.09	1.00	126.5	98.4	3.77	2.28	0.34
.018	5.63	5.13	4.93	4.74	4.55	4.36	4.19	3.76	3.38	3.06	2.77	2.23	1.83	1.14	0.78	0.29	0.18	0.10	1.00	131.9	108.1	3.82	2.28	0.38
020	5.71	5.20	5.00	4.81	4.62	4.42	4.25	3.82	3.44	3.12	2.84	2.28	1.92	1.21	0.85	0.32	0.20	0.11	1.00	137.3	117.4	3.87	2.27	0.41
022	5.79	5.28	5.07	4.88	4.68	4.49	4.31	3.88	3.50	3.18	2.90	2.36	2.00	1.30	0.91	0.35	0.21	0.12	1.00	142.7	126.5	3.91	2.27	0.44
.024	5.87	5.35	5.14	4.95	4.75	4.55	4.37	3.93	3.57	3.23	2.96	2.43	2.07	1.39	0.97	0.37	0.23	0.13	1.00	148.1	135.3	3.96	2.26	0.47
.026	5.96	5.43	5.21	5.01	4.82	4.61	4.44	3.99	3.63	3.29	3.02	2.50	2.12	1.45	1.02	0.40	0.24	0.14	1.00	153.5	143.9	4.01	2.26	0.51
.028	6.04	5.50	5.28	5.08	4.88	4.68	4.50	4.05	3.69	3.34	3.08	2.56	2.16	1.55	1.08	0.42	0.26	0.15	1.00	158.9	152.4	4.05	2.25	0.54
030	6.12	5.57	5.36	5.15	4.95	4.74	4.56	4.11	3.74	3.39	3.14	2.62	2.19	1.61	1.15	0.55	0.34	0.20	1.00	164.3	160.6	4.10	2.25	0.57
.032	6.20	5.65	5.43	5.22	5.01	4.81	4.62	4.17	3.80	3.44	3.19	2.67	2.23	1.66	1.19	0.47	0.29	0.16	1.01	169.7	168.7	4.15	2.24	0.60
.034	6.29	5.72	5.50	5.29	5.08	4.87	4.69	4.23	3.86	3.49	3.25	2.73	2.28	1.73	1.26	0.49	0.30	0.17	1.03	175.1	176.7	4.19	2.23	0.63
.036	6.37	5.80	5.57	5.36	5.15	4.93	4.75	4.28	3.92	3.54	3.30	2.79	2.34	1.80	1.32	0.51	0.32	0.18	1.04	180.5	184.5	4.24	2.23	0.67
.038	6.45	5.87	5.64	5.42	5.21	5.00	4.81	4.34	3.97	3.60	3.35	2.85	2.40	1.86	1.37	0.54	0.33	0.19	1.06	185.9	192.2	4.29	2.22	0.70
.040	6.53	5.94	5.71	5.49	5.28	5.06	4.87	4.40	4.03	3.66	3.40	2.91	2.46	1.91	1.43	0.56	0.35	0.20	1.07	191.3	199.8	4.33	2.22	0.73
.042	6.62	6.02	5.78	5.56	5.35	5.13	4.93	4.46	4.09	3.71	3.45	2.92	2.51	1.97	1.49	0.59	0.36	0.21	1.09	196.7	207.2	4.38	2.21	0.76
044	6.70	6.09	5.85	5.63	5.41	5.19	5.00	4.52	4.14	3.77	3.50	2.97	2.57	2.01	1.54	0.61	0.38	0.21	1.10	202.1	214.6	4.43	2.21	0.79
.046	6.78	6.17	5.92	5.70	5.48	5.25	5.06	4.58	4.20	3.83	3.55	3.01	2.62	2.04	1.58	0.63	0.39	0.22	1.12	207.5	221.9	4.47	2.20	0.82
.048	6.86	6.24	5.99	5.77	5.54	5.32	5.12	4.64	4.25	3.88	3.59	3.06	2.67	2.07	1.63	0.66	0.41	0.23	1.13	212.9	229.0	4.52	2.20	0.85
.050	6.95	6.31	6.07	5.84	5.61	5.38	5.18	4.70	4.31	3.94	3.64	3.11	2.71	2.09	1.68	0.68	0.42	0.24	1.14	218.3	236.1	4.57	2.19	0.89
.052	7.03	6.39	6.14	5.90	5.68	5.45	5.24	4.76	4.36	4.00	3.68	3.16	2.76	2.11	1.73	0.70	0.44	0.25	1.16	223.7	243.2	4.61	2.19	0.92
.054	7.11	6.46	6.21	5.97	5.74	5.51	5.30	4.82	4.42	4.05	3.73	3.20	2.80	2.13	1.78	0.73	0.45	0.26	1.17	229.1	250.1	4.66	2.18	0.95
.056	7.19	6.54	6.28	6.04	5.81	5.57	5.37	4.88	4.47	4.11	3.77	3.25	2.85	2.15	1.83	0.75	0.47	0.26	1.19	234.5	257.0	4.71	2.18	0.98
.058	7.28	6.61	6.35	6.11	5.88	5.64	5.43	4.94	4.53	4.16	3.82	3.30	2.91	2.16	1.87	0.77	0.48	0.27	1.20	239.9	263.8	4.75	2.17	1.01
.060	7.36	6.69	6.42	6.18	5.94	5.70	5.49	4.99	4.58	4.21	3.86	3.34	2.92	2.20	1.91	0.80	0.50	0.28	1.21	245.3	270.5	4.80	2.17	1.04
.062	7.44	6.76	6.49	6.25	6.01	5.76	5.55	5.05	4.64	4.27	3.90	3.39	2.97	2.26	1.95	0.82	0.51	0.29	1.23	250.7	277.2	4.85	2.16	1.07
.064	7.52	6.83	6.56	6.31	6.07	5.83	5.61	5.11	4.69	4.32	3.95	3.43	3.01	2.31	1.97	0.85	0.53	0.30	1.24	256.1	283.8	4.89	2.16	1.10
.066	7.60	6.91	6.63	6.38	6.14	5.89	5.67	5.17	4.74	4.37	3.99	3.48	3.05	2.36	1.99	0.87	0.54	0.31	1.25	261.5	290.4	4.94	2.15	1.14
.068	7.69	6.98	6.70	6.45	6.21	5.96	5.73	5.23	4.80	4.43	4.04	3.52	3.09	2.41	2.01	0.90	0.56	0.32	1.27	266.9	297.0	4.99	2.14	1.17
.070	7.77	7.06	6.77	6.52	6.27	6.02	5.80	5.29	4.85	4.48	4.09	3.57	3.13	2.45	2.02	0.92	0.57	0.32	1.28	272.3	303.4	5.03	2.14	1.20
072	7.85	7.13	6.85	6.59	6.34	6.08	5.86	5.35	4.90	4.53	4.14	3.61	3.17	2.50	2.04	0.94	0.58	0.33	1.29	277.7	309.9	5.08	2.13	1.23
.074	7.93	7.20	6.92	6.66	6.41	6.15	5.92	5.40	4.96	4.59	4.20	3.66	3.21	2.54	2.05	0.96	0.60	0.34	1.30	283.1	316.3	5.13	2.13	1.26
.076	8.02	7.28	6.99	6.72	6.47	6.21	5.98	5.46	5.01	4.64	4.25	3.70	3.25	2.58	2.06	0.99	0.61	0.35	1.32	288.5	322.6	5.17	2.12	1.29
.078	8.10	7.35	7.06	6.79	6.54	6.28	6.04	5.52	5.06	4.69	4.30	3.74	3.29	2.62	2.07	1.01	0.63	0.36	1.33	293.9	328.9	5.22	2.12	1.32
.080	8.18	7.43	7.13	6.86	6.60	6.34	6.10	5.58	5.11	4.68	4.35	3.79	3.34	2.66	2.08	1.03	0.64	0.37	1.34	299.3	335.2	5.27	2.11	1.35

L/t_e	VALUES OF MOMENT MULTIPLIERS δ — VALUES OF ULTIMATE STRESS P_u/A_g IN KSI: 0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02
3.0	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.05	1.05
4.0	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.05	1.05	1.06	1.07	1.08	1.08	1.09
5.0	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.08	1.09	1.10	1.11	1.13	1.14	1.15
6.0	1.00	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.07	1.11	1.13	1.15	1.17	1.19	1.21	1.23
7.0	1.01	1.01	1.02	1.02	1.03	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.08	1.09	1.10	1.16	1.19	1.22	1.25	1.28	1.31	1.35
8.0	1.01	1.02	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.08	1.09	1.10	1.11	1.12	1.13	1.22	1.26	1.30	1.35	1.40	1.45	1.51
9.0	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.11	1.12	1.13	1.15	1.16	1.17	1.30	1.36	1.42	1.49	1.57	1.65	1.74
10.0	1.01	1.02	1.04	1.05	1.06	1.08	1.09	1.11	1.12	1.14	1.15	1.17	1.19	1.21	1.22	1.40	1.48	1.57	1.68	1.80	1.95	2.11
11.0	1.01	1.03	1.05	1.06	1.08	1.10	1.11	1.13	1.15	1.17	1.19	1.21	1.24	1.26	1.28	1.52	1.65	1.79	1.96	2.17	2.43	2.76
12.0	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.19	1.21	1.24	1.27	1.29	1.32	1.36	1.69	1.88	2.11	2.40	2.79	3.34	4.14
13.0	1.02	1.04	1.07	1.09	1.11	1.14	1.17	1.20	1.23	1.26	1.29	1.33	1.36	1.40	1.45	1.92	2.21	2.61	3.17	4.06	5.62	9.13
14.0	1.02	1.05	1.08	1.11	1.14	1.17	1.20	1.24	1.27	1.31	1.36	1.40	1.45	1.50	1.56	2.25	2.74	3.51	4.86	7.92		
15.0	1.03	1.06	1.09	1.12	1.16	1.20	1.24	1.28	1.33	1.38	1.43	1.49	1.55	1.62	1.70	2.76	3.70	5.58				
16.0	1.03	1.07	1.10	1.14	1.18	1.23	1.28	1.33	1.39	1.45	1.52	1.60	1.68	1.77	1.88	3.65	5.88					
17.0	1.04	1.08	1.12	1.16	1.21	1.27	1.33	1.39	1.46	1.54	1.63	1.73	1.84	1.97	2.11	5.55						
18.0	1.04	1.09	1.13	1.19	1.25	1.31	1.38	1.46	1.55	1.65	1.76	1.90	2.05	2.23	2.44							

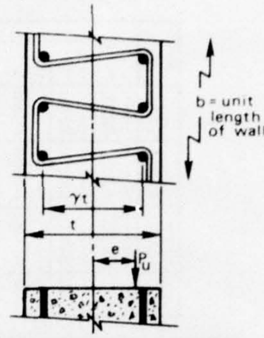
VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .75$ — VALUES OF ECCENTRICITY RATIO $\delta e/t$

P_g Steel Ratio	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.t Ratio t_e/t	EI_b/bt^3	EI_t/bt^3	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	M_u/bt^2
.010	5.26	4.77	4.57	4.39	4.20	4.02	3.84	3.43	3.04	2.74	2.41	1.80	1.31	0.74	0.48	0.17	0.10	0.06	1.00	125.5	82.3	3.95	2.52	0.23
.012	5.35	4.85	4.65	4.46	4.27	4.09	3.91	3.50	3.12	2.83	2.52	1.93	1.45	0.84	0.55	0.20	0.12	0.07	1.00	134.0	96.1	4.00	2.51	0.27
.014	5.43	4.92	4.72	4.53	4.34	4.16	3.99	3.57	3.20	2.90	2.62	2.04	1.57	0.95	0.63	0.23	0.14	0.08	1.00	142.4	109.4	4.05	2.51	0.31
.016	5.51	5.00	4.80	4.61	4.42	4.23	4.06	3.64	3.28	2.98	2.71	2.15	1.67	1.05	0.70	0.26	0.16	0.08	1.00	150.8	122.3	4.09	2.50	0.35
.018	5.59	5.08	4.87	4.68	4.49	4.30	4.13	3.71	3.36	3.04	2.79	2.26	1.79	1.15	0.78	0.29	0.17	0.10	1.00	159.3	134.9	4.14	2.50	0.39
.020	5.68	5.15	4.95	4.75	4.56	4.37	4.20	3.77	3.43	3.11	2.86	2.35	1.89	1.22	0.86	0.32	0.19	0.11	1.00	167.7	147.1	4.19	2.49	0.43
022	5.76	5.23	5.02	4.82	4.63	4.44	4.27	3.84	3.50	3.16	2.93	2.44	1.98	1.32	0.93	0.34	0.21	0.12	1.03	176.1	159.1	4.23	2.48	0.47
024	5.84	5.31	5.10	4.90	4.71	4.51	4.33	3.91	3.57	3.23	3.00	2.52	2.06	1.41	1.00	0.37	0.23	0.13	1.05	184.6	170.8	4.28	2.48	0.51
.026	5.93	5.38	5.17	4.97	4.78	4.58	4.40	3.98	3.63	3.30	3.06	2.60	2.15	1.49	1.07	0.40	0.24	0.14	1.08	193.0	182.4	4.33	2.47	0.55
028	6.01	5.46	5.25	5.04	4.85	4.65	4.47	4.05	3.70	3.37	3.11	2.64	2.23	1.56	1.13	0.43	0.26	0.15	1.10	201.5	193.7	4.37	2.47	0.59
.030	6.09	5.54	5.32	5.11	4.92	4.72	4.53	4.12	3.76	3.44	3.17	2.70	2.31	1.62	1.19	0.46	0.28	0.16	1.12	209.9	204.8	4.42	2.46	0.63
.032	6.18	5.61	5.40	5.18	4.99	4.79	4.60	4.19	3.82	3.50	3.22	2.76	2.38	1.70	1.26	0.48	0.30	0.17	1.14	218.3	215.8	4.47	2.46	0.67
.034	6.26	5.69	5.47	5.25	5.06	4.86	4.66	4.25	3.88	3.57	3.27	2.81	2.44	1.78	1.31	0.51	0.31	0.18	1.17	226.8	226.6	4.51	2.45	0.70
.036	6.34	5.77	5.55	5.32	5.13	4.93	4.73	4.32	3.94	3.63	3.31	2.87	2.53	1.85	1.37	0.54	0.33	0.19	1.19	235.2	237.3	4.56	2.45	0.74
.038	6.42	5.84	5.62	5.40	5.20	5.00	4.80	4.39	4.00	3.70	3.38	2.92	2.56	1.91	1.43	0.57	0.35	0.20	1.21	243.6	247.9	4.61	2.44	0.78
.040	6.51	5.92	5.69	5.47	5.27	5.07	4.87	4.45	4.06	3.76	3.44	2.98	2.51	1.97	1.49	0.60	0.36	0.21	1.23	252.1	258.3	4.65	2.44	0.82
.042	6.59	5.99	5.77	5.54	5.34	5.14	4.93	4.52	4.11	3.82	3.51	3.03	2.66	2.02	1.55	0.63	0.38	0.22	1.25	260.5	268.6	4.70	2.43	0.86
.044	6.67	6.07	5.84	5.61	5.41	5.21	5.00	4.58	4.17	3.88	3.57	3.08	2.71	2.09	1.59	0.65	0.40	0.23	1.27	269.0	278.8	4.75	2.43	0.90
.046	6.76	6.15	5.92	5.68	5.48	5.28	5.07	4.64	4.23	3.94	3.63	3.14	2.76	2.15	1.66	0.68	0.42	0.23	1.29	277.4	288.9	4.79	2.42	0.94
.048	6.84	6.22	5.99	5.75	5.55	5.35	5.14	4.71	4.28	3.99	3.69	3.19	2.81	2.21	1.72	0.71	0.43	0.24	1.31	285.8	299.0	4.84	2.42	0.98
.050	6.92	6.30	6.06	5.83	5.62	5.41	5.21	4.77	4.35	4.05	3.75	3.24	2.86	2.26	1.77	0.74	0.45	0.25	1.33	294.3	308.9	4.89	2.41	1.02
.052	7.00	6.37	6.14	5.90	5.69	5.48	5.27	4.83	4.41	4.10	3.76	3.28	2.91	2.31	1.82	0.76	0.47	0.26	1.35	302.7	318.8	4.93	2.41	1.06
.054	7.09	6.45	6.21	5.97	5.76	5.55	5.34	4.90	4.47	4.16	3.81	3.33	2.96	2.36	1.87	0.79	0.49	0.27	1.37	311.1	328.6	4.98	2.40	1.09
.056	7.17	6.52	6.29	6.04	5.82	5.62	5.41	4.96	4.54	4.21	3.87	3.38	3.00	2.41	1.92	0.82	0.50	0.28	1.38	319.6	338.3	5.03	2.39	1.13
.058	7.25	6.60	6.36	6.11	5.89	5.69	5.47	5.02	4.60	4.27	3.92	3.45	3.05	2.48	1.96	0.85	0.52	0.29	1.40	328.0	347.9	5.07	2.39	1.17
060	7.33	6.68	6.43	6.19	5.96	5.75	5.54	5.08	4.66	4.32	3.98	3.49	3.10	2.50	2.00	0.88	0.54	0.30	1.42	336.5	357.5	5.12	2.38	1.21
.062	7.42	6.75	6.51	6.26	6.03	5.82	5.61	5.14	4.72	4.37	4.03	3.53	3.14	2.54	2.05	0.90	0.56	0.31	1.44	344.9	367.0	5.17	2.38	1.25
.064	7.50	6.83	6.58	6.33	6.10	5.89	5.67	5.20	4.78	4.43	4.08	3.56	3.19	2.58	2.10	0.93	0.57	0.32	1.46	353.3	376.5	5.21	2.37	1.29
.066	7.58	6.90	6.66	6.40	6.17	5.96	5.74	5.26	4.84	4.48	4.14	3.61	3.23	2.62	2.14	0.96	0.59	0.33	1.47	361.8	385.9	5.26	2.37	1.33
.068	7.67	6.98	6.73	6.47	6.24	6.02	5.81	5.33	4.90	4.53	4.19	3.66	3.28	2.66	2.19	0.98	0.61	0.34	1.49	370.2	395.2	5.31	2.36	1.37
.070	7.75	7.05	6.80	6.55	6.30	6.09	5.87	5.39	4.96	4.58	4.24	3.72	3.32	2.70	2.23	1.01	0.62	0.35	1.51	378.6	404.5	5.35	2.36	1.41
.072	7.83	7.13	6.88	6.62	6.37	6.16	5.94	5.45	5.02	4.63	4.29	3.78	3.36	2.74	2.26	1.04	0.64	0.36	1.52	387.1	413.8	5.40	2.35	1.44
.074	7.91	7.20	6.95	6.69	6.44	6.23	6.01	5.51	5.08	4.68	4.35	3.83	3.41	2.78	2.30	1.06	0.66	0.37	1.54	395.5	423.0	5.45	2.35	1.48
.076	8.00	7.28	7.02	6.76	6.51	6.29	6.07	5.57	5.14	4.73	4.40	3.89	3.45	2.79	2.33	1.08	0.68	0.38	1.56	404.0	432.2	5.49	2.34	1.52
.078	8.08	7.35	7.10	6.83	6.58	6.36	6.14	5.63	5.20	4.78	4.45	3.89	3.49	2.83	2.40	1.11	0.69	0.39	1.57	412.4	441.3	5.54	2.34	1.56
080	8.16	7.43	7.17	6.90	6.64	6.43	6.20	5.69	5.26	4.83	4.50	3.93	3.53	2.87	2.42	1.13	0.71	0.40	1.59	420.8	450.4	5.59	2.33	1.60

VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .9$ — VALUES OF ECCENTRICITY RATIO $\delta e/t$

P_g Steel Ratio	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.t Ratio t_e/t	EI_b/bt^3	EI_t/bt^3	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	M_u/bt^2
.010	5.24	4.72	4.52	4.33	4.13	3.95	3.78	3.37	2.99	2.64	2.31	1.69	1.24	0.72	0.48	0.17	0.10	0.06	1.00	144.1	100.5	4.27	2.73	0.24
.012	5.33	4.81	4.60	4.41	4.22	4.03	3.86	3.45	3.09	2.73	2.44	1.85	1.39	0.82	0.56	0.20	0.12	0.07	1.00	156.2	117.8	4.32	2.73	0.29
.014	5.41	4.89	4.68	4.49	4.30	4.11	3.94	3.53	3.19	2.84	2.55	1.98	1.52	0.93	0.65	0.23	0.14	0.08	1.01	168.4	134.7	4.36	2.72	0.33
.016	5.50	4.97	4.76	4.57	4.38	4.19	4.02	3.61	3.27	2.94	2.64	2.09	1.63	1.04	0.72	0.26	0.16	0.09	1.04	180.5	151.2	4.41	2.72	0.38
.018	5.58	5.05	4.84	4.65	4.46	4.27	4.10	3.69	3.36	3.03	2.71	2.22	1.75	1.13	0.80	0.30	0.18	0.10	1.08	192.7	167.3	4.46	2.71	0.43
.020	5.67	5.13	4.92	4.72	4.54	4.35	4.17	3.77	3.44	3.12	2.80	2.33	1.87	1.22	0.87	0.33	0.20	0.11	1.11	204.8	183.0	4.50	2.71	0.47
.022	5.75	5.21	5.00	4.80	4.61	4.43	4.24	3.85	3.51	3.20	2.89	2.43	1.96	1.33	0.95	0.36	0.22	0.12	1.14	217.0	198.5	4.55	2.70	0.52
.024	5.84	5.29	5.08	4.87	4.69	4.50	4.32	3.93	3.58	3.28	2.98	2.51	2.05	1.42	1.02	0.39	0.24	0.13	1.17	229.1	213.8	4.60	2.70	0.57
.026	5.92	5.37	5.16	4.95	4.77	4.58	4.39	4.00	3.65	3.36	3.06	2.57	2.15	1.50	1.09	0.42	0.26	0.14	1.20	241.3	228.8	4.64	2.69	0.61
.028	6.00	5.45	5.24	5.03	4.84	4.66	4.47	4.08	3.71	3.43	3.14	2.62	2.25	1.58	1.17	0.45	0.28	0.15	1.23	253.4	243.6	4.69	2.69	0.66
.030	6.09	5.53	5.32	5.11	4.92	4.73	4.55	4.15	3.77	3.50	3.22	2.67	2.33	1.65	1.22	0.48	0.30	0.16	1.26	265.6	258.3	4.74	2.68	0.71
032	6.17	5.61	5.40	5.18	4.99	4.81	4.62	4.22	3.84	3.57	3.29	2.75	2.41	1.73	1.28	0.52	0.31	0.18	1.29	277.7	272.7	4.78	2.68	0.76
.034	6.26	5.68	5.48	5.26	5.06	4.88	4.70	4.29	3.91	3.63	3.36	2.83	2.48	1.81	1.35	0.55	0.33	0.19	1.32	289.9	287.0	4.83	2.67	0.80
.036	6.34	5.76	5.55	5.34	5.14	4.95	4.77	4.36	3.99	3.69	3.43	2.90	2.53	1.88	1.41	0.58	0.35	0.20	1.35	302.0	301.2	4.88	2.67	0.85
.038	6.42	5.84	5.63	5.42	5.21	5.03	4.84	4.43	4.06	3.75	3.45	2.97	2.57	1.95	1.47	0.61	0.37	0.21	1.37	314.2	315.2	4.92	2.66	0.90
.040	6.51	5.92	5.71	5.49	5.28	5.10	4.91	4.49	4.13	3.81	3.51	3.04	2.60	2.01	1.54	0.64	0.39	0.22	1.40	326.3	329.1	4.97	2.65	0.94
.042	6.60	6.00	5.78	5.57	5.35	5.17	4.99	4.56	4.20	3.87	3.57	3.11	2.64	2.08	1.59	0.67	0.41	0.23	1.43	338.5	342.9	5.02	2.65	0.99
.044	6.69	6.08	5.86	5.64	5.42	5.24	5.06	4.62	4.27	3.92	3.63	3.17	2.70	2.15	1.66	0.70	0.43	0.24	1.45	350.6	356.6	5.06	2.64	1.04
.046	6.79	6.16	5.94	5.72	5.50	5.31	5.13	4.69	4.33	3.98	3.69	3.24	2.77	2.22	1.72	0.73	0.45	0.25	1.48	362.8	370.2	5.11	2.64	1.08
.048	6.88	6.23	6.01	5.80	5.57	5.38	5.20	4.75	4.40	4.03	3.75	3.31	2.84	2.28	1.78	0.76	0.47	0.26	1.50	374.9	383.7	5.16	2.63	1.13
.050	6.97	6.31	6.09	5.87	5.65	5.45	5.27	4.81	4.46	4.10	3.85	3.33	2.91	2.34	1.84	0.79	0.49	0.27	1.52	387.1	397.1	5.20	2.63	1.18
.052	7.07	6.39	6.16	5.95	5.72	5.52	5.34	4.87	4.53	4.17	3.91	3.38	2.97	2.39	1.89	0.82	0.51	0.28	1.55	399.2	410.4	5.25	2.62	1.22
.054	7.16	6.47	6.24	6.02	5.80	5.59	5.41	4.94	4.59	4.23	3.96	3.44	3.03	2.43	1.94	0.84	0.52	0.30	1.57	411.4	423.6	5.30	2.62	1.27
.056	7.25	6.55	6.31	6.09	5.87	5.66	5.48	5.01	4.65	4.30	4.01	3.49	3.09	2.46	1.98	0.87	0.54	0.31	1.59	423.5	436.8	5.34	2.61	1.32
.058	7.34	6.63	6.39	6.17	5.94	5.73	5.55	5.08	4.72	4.36	4.06	3.54	3.14	2.49	2.04	0.90	0.56	0.32	1.62	435.7	449.9	5.39	2.61	1.36
.060	7.43	6.71	6.46	6.24	6.02	5.79	5.61	5.15	4.78	4.43	4.11	3.60	3.20	2.51	2.10	0.93	0.58	0.33	1.64	447.8	462.9	5.44	2.60	1.41
.062	7.52	6.79	6.54	6.32	6.09	5.86	5.68	5.21	4.84	4.49	4.16	3.65	3.26	2.54	2.15	0.96	0.60	0.34	1.66	460.0	475.9	5.48	2.60	1.46
064	7.61	6.87	6.61	6.39	6.16	5.93	5.75	5.28	4.90	4.55	4.21	3.70	3.32	2.56	2.20	0.99	0.62	0.35	1.68	472.1	488.8	5.53	2.59	1.50
066	7.70	6.95	6.69	6.46	6.24	6.00	5.82	5.35	4.96	4.61	4.25	3.76	3.34	2.58	2.25	1.02	0.64	0.36	1.70	484.3	501.7	5.58	2.59	1.55
.068	7.79	7.02	6.76	6.54	6.31	6.07	5.88	5.42	5.02	4.68	4.32	3.81	3.38	2.62	2.30	1.04	0.65	0.37	1.73	496.4	514.5	5.62	2.58	1.60
.070	7.88	7.10	6.84	6.61	6.38	6.15	5.95	5.48	5.08	4.74	4.38	3.86	3.43	2.69	2.34	1.07	0.67	0.38	1.75	508.6	527.2	5.67	2.58	1.64
.072	7.97	7.18	6.91	6.69	6.45	6.22	6.02	5.55	5.14	4.80	4.44	3.91	3.48	2.74	2.37	1.10	0.69	0.39	1.77	520.7	539.9	5.72	2.57	1.69
.074	8.05	7.26	6.99	6.76	6.53	6.29	6.08	5.62	5.19	4.86	4.50	3.96	3.53	2.80	2.39	1.13	0.71	0.40	1.79	532.9	552.5	5.76	2.56	1.74
.076	8.13	7.34	7.06	6.83	6.60	6.36	6.15	5.68	5.25	4.92	4.56	4.01	3.57	2.86	2.41	1.16	0.73	0.41	1.81	545.0	565.1	5.81	2.56	1.78
.078	8.21	7.42	7.14	6.90	6.67	6.43	6.22	5.75	5.31	4.97	4.62	4.06	3.62	2.91	2.43	1.18	0.75	0.42	1.83	557.2	577.7	5.86	2.55	1.83
.080	8.29	7.49	7.22	6.98	6.74	6.50	6.28	5.81	5.37	5.03	4.68	4.11	3.67	2.96	2.45	1.21	0.76	0.43	1.85	569.3	590.2	5.90	2.55	1.88

Table 6.6A.4 Values of ultimate axial stress, P_u/A_g, for rectangular column with symmetric reinforcing steel, f'_c = 3 ksi, f_{dy} = 72 ksi, γ = 0.45, 0.60, 0.75, 0.90



p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .45																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	VALUES OF ECCENTRICITY RATIO δe/t																							
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	3.53	3.24	3.13	3.02	2.90	2.79	2.68	2.42	2.15	1.92	1.72	1.39	1.15	0.80	0.57	0.22	0.14	0.08	1.00	65.2	49.2	2.30	1.03	0.27
.012	3.64	3.34	3.23	3.11	2.99	2.88	2.77	2.50	2.22	1.99	1.78	1.44	1.21	0.86	0.63	0.25	0.16	0.09	1.00	68.2	56.3	2.36	1.00	0.30
.014	3.76	3.45	3.33	3.21	3.08	2.97	2.85	2.58	2.29	2.06	1.84	1.50	1.27	0.92	0.70	0.28	0.18	0.10	1.00	71.3	63.0	2.43	0.97	0.34
.016	3.87	3.55	3.43	3.30	3.17	3.06	2.94	2.66	2.36	2.12	1.89	1.55	1.31	0.97	0.76	0.31	0.19	0.11	1.00	74.3	69.4	2.50	0.94	0.37
.018	3.99	3.65	3.53	3.40	3.27	3.14	3.02	2.73	2.43	2.19	1.94	1.61	1.36	1.02	0.80	0.34	0.21	0.12	1.00	77.3	75.4	2.56	0.90	0.41
.020	4.11	3.76	3.62	3.49	3.36	3.23	3.11	2.81	2.49	2.26	2.00	1.66	1.40	1.07	0.84	0.36	0.23	0.13	1.00	80.4	81.2	2.63	0.87	0.44
.022	4.22	3.86	3.72	3.59	3.45	3.32	3.19	2.89	2.56	2.32	2.07	1.72	1.45	1.11	0.90	0.39	0.25	0.14	1.00	83.4	86.8	2.70	0.84	0.48
.024	4.34	3.96	3.82	3.68	3.54	3.41	3.28	2.97	2.63	2.39	2.13	1.77	1.50	1.14	0.92	0.42	0.26	0.15	1.00	86.5	92.2	2.76	0.81	0.51
.026	4.46	4.07	3.92	3.78	3.63	3.50	3.36	3.04	2.69	2.45	2.20	1.83	1.55	1.18	0.96	0.44	0.28	0.16	1.00	89.5	97.4	2.83	0.77	0.54
.028	4.57	4.17	4.02	3.87	3.72	3.58	3.44	3.12	2.76	2.52	2.26	1.88	1.60	1.22	0.99	0.47	0.29	0.17	1.00	92.5	102.4	2.90	0.74	0.57
.030	4.69	4.27	4.12	3.97	3.81	3.67	3.53	3.20	2.83	2.58	2.32	1.93	1.62	1.26	1.02	0.49	0.31	0.18	1.00	95.6	107.3	2.96	0.71	0.61
.032	4.80	4.38	4.22	4.06	3.90	3.76	3.61	3.28	2.90	2.65	2.39	1.98	1.67	1.29	1.05	0.51	0.33	0.19	1.00	98.6	112.1	3.03	0.68	0.64
.034	4.92	4.48	4.32	4.16	3.99	3.85	3.70	3.35	2.97	2.71	2.40	2.01	1.72	1.32	1.08	0.54	0.34	0.20	1.01	101.6	116.8	3.10	0.64	0.67
.036	5.04	4.59	4.42	4.25	4.08	3.93	3.78	3.43	3.04	2.78	2.46	2.06	1.76	1.35	1.11	0.56	0.36	0.21	1.02	104.7	121.4	3.16	0.61	0.70
.038	5.15	4.69	4.52	4.35	4.17	4.02	3.87	3.51	3.11	2.84	2.52	2.11	1.81	1.39	1.14	0.57	0.37	0.22	1.04	107.7	125.9	3.23	0.58	0.74
.040	5.27	4.79	4.62	4.44	4.27	4.11	3.95	3.59	3.18	2.86	2.57	2.18	1.85	1.43	1.17	0.60	0.39	0.22	1.05	110.8	130.3	3.30	0.54	0.77
.042	5.39	4.90	4.72	4.54	4.36	4.20	4.03	3.66	3.25	2.92	2.63	2.22	1.90	1.47	1.19	0.62	0.41	0.23	1.07	113.8	134.6	3.36	0.51	0.80
.044	5.50	5.00	4.81	4.63	4.45	4.28	4.12	3.74	3.32	2.98	2.69	2.27	1.94	1.49	1.22	0.63	0.42	0.24	1.08	116.8	138.9	3.43	0.48	0.83
.046	5.62	5.10	4.91	4.73	4.54	4.37	4.20	3.82	3.39	3.04	2.75	2.32	1.99	1.52	1.25	0.65	0.44	0.25	1.09	119.9	143.1	3.50	0.45	0.86
.048	5.74	5.21	5.01	4.82	4.63	4.46	4.29	3.90	3.46	3.10	2.80	2.36	2.01	1.56	1.28	0.66	0.45	0.26	1.11	122.9	147.2	3.56	0.41	0.89
.050	5.86	5.31	5.11	4.92	4.72	4.55	4.37	3.97	3.53	3.17	2.86	2.41	2.06	1.60	1.30	0.68	0.46	0.27	1.12	125.9	151.3	3.63	0.38	0.93
.052	5.97	5.41	5.21	5.02	4.81	4.64	4.46	4.05	3.60	3.23	2.92	2.46	2.10	1.63	1.33	0.69	0.47	0.28	1.14	129.0	155.3	3.70	0.35	0.96
.054	6.09	5.52	5.31	5.11	4.90	4.72	4.54	4.13	3.67	3.29	2.98	2.50	2.14	1.67	1.36	0.71	0.48	0.29	1.15	132.0	159.2	3.76	0.32	0.99
.056	6.21	5.62	5.41	5.21	4.99	4.81	4.63	4.20	3.74	3.35	3.03	2.56	2.19	1.69	1.39	0.72	0.49	0.29	1.16	135.1	163.2	3.83	0.28	1.02
.058	6.32	5.73	5.51	5.30	5.08	4.90	4.71	4.28	3.81	3.42	3.09	2.60	2.23	1.73	1.41	0.74	0.50	0.30	1.18	138.1	167.1	3.90	0.25	1.05
.060	6.44	5.83	5.61	5.40	5.17	4.99	4.79	4.36	3.88	3.48	3.15	2.64	2.27	1.76	1.44	0.75	0.51	0.31	1.19	141.1	170.9	3.96	0.22	1.08
.062	6.56	5.93	5.71	5.49	5.26	5.07	4.88	4.44	3.95	3.54	3.20	2.68	2.32	1.79	1.46	0.76	0.52	0.32	1.20	144.2	174.7	4.03	0.18	1.11
.064	6.67	6.04	5.81	5.59	5.36	5.16	4.96	4.51	4.02	3.60	3.26	2.72	2.36	1.83	1.49	0.78	0.53	0.32	1.21	147.2	178.5	4.10	0.15	1.15
.066	6.79	6.14	5.91	5.68	5.45	5.25	5.05	4.59	4.09	3.66	3.32	2.76	2.40	1.87	1.52	0.80	0.54	0.33	1.23	150.2	182.2	4.16	0.12	1.18
.068	6.91	6.25	6.01	5.78	5.54	5.34	5.13	4.67	4.16	3.73	3.38	2.81	2.45	1.90	1.55	0.81	0.55	0.33	1.24	153.3	185.9	4.23	0.09	1.21
.070	7.02	6.35	6.11	5.87	5.63	5.43	5.22	4.75	4.23	3.79	3.43	2.87	2.49	1.94	1.57	0.82	0.56	0.34	1.25	156.3	189.6	4.30	0.05	1.24
.072	7.14	6.45	6.20	5.97	5.72	5.51	5.30	4.82	4.30	3.85	3.49	2.92	2.53	1.96	1.60	0.84	0.57	0.35	1.26	159.4	193.2	4.36	0.02	1.27
.074	7.26	6.56	6.30	6.06	5.81	5.60	5.38	4.90	4.37	3.91	3.55	2.98	2.56	1.99	1.63	0.85	0.58	0.35	1.27	162.4	196.8	4.43	-.01	1.30
.076	7.38	6.66	6.40	6.16	5.90	5.69	5.47	4.98	4.44	3.97	3.61	3.03	2.60	2.03	1.66	0.87	0.59	0.36	1.29	165.4	200.4	4.50	-.04	1.32
.078	7.49	6.77	6.50	6.25	5.99	5.78	5.55	5.05	4.51	4.04	3.66	3.08	2.64	2.06	1.69	0.88	0.60	0.36	1.30	168.5	204.0	4.56	-.08	1.34
.080	7.61	6.87	6.60	6.35	6.08	5.86	5.64	5.13	4.58	4.10	3.72	3.14	2.68	2.09	1.71	0.90	0.61	0.37	1.31	171.5	207.6	4.63	-.11	1.37

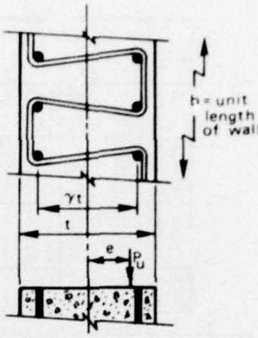
p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	VALUES OF ECCENTRICITY RATIO δe/t																							
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	3.52	3.21	3.10	2.98	2.86	2.75	2.64	2.39	2.15	1.95	1.76	1.46	1.20	0.79	0.56	0.22	0.13	0.07	1.00	77.0	61.0	2.51	1.28	0.28
.012	3.64	3.32	3.20	3.08	2.96	2.85	2.74	2.48	2.23	2.04	1.84	1.55	1.29	0.89	0.63	0.25	0.15	0.08	1.00	82.4	70.5	2.58	1.27	0.32
.014	3.76	3.43	3.30	3.18	3.06	2.94	2.83	2.56	2.32	2.12	1.93	1.63	1.40	0.98	0.71	0.28	0.17	0.10	1.00	87.8	79.5	2.65	1.26	0.36
.016	3.88	3.53	3.40	3.28	3.16	3.04	2.92	2.65	2.40	2.20	2.01	1.71	1.46	1.07	0.79	0.31	0.20	0.11	1.00	93.2	88.2	2.72	1.25	0.41
.018	4.00	3.64	3.51	3.38	3.25	3.13	3.02	2.73	2.49	2.28	2.10	1.78	1.53	1.14	0.86	0.35	0.22	0.12	1.00	98.6	96.5	2.79	1.24	0.45
.020	4.12	3.75	3.61	3.48	3.35	3.22	3.11	2.82	2.57	2.35	2.17	1.84	1.60	1.20	0.93	0.38	0.24	0.13	1.02	104.0	104.6	2.86	1.23	0.50
.022	4.24	3.85	3.71	3.58	3.45	3.32	3.20	2.90	2.66	2.43	2.25	1.93	1.68	1.27	1.00	0.41	0.26	0.15	1.05	109.4	112.5	2.92	1.22	0.54
.024	4.36	3.96	3.82	3.68	3.55	3.41	3.29	2.99	2.74	2.50	2.33	1.98	1.73	1.35	1.07	0.44	0.28	0.16	1.07	114.8	120.1	2.99	1.22	0.58
.026	4.48	4.07	3.92	3.78	3.64	3.50	3.38	3.07	2.82	2.57	2.40	2.03	1.79	1.40	1.11	0.48	0.30	0.17	1.10	120.2	127.6	3.06	1.21	0.63
.028	4.60	4.18	4.02	3.88	3.74	3.60	3.47	3.16	2.90	2.64	2.47	2.11	1.85	1.46	1.16	0.51	0.32	0.18	1.12	125.6	135.0	3.13	1.20	0.67
.030	4.72	4.28	4.13	3.98	3.84	3.69	3.56	3.24	2.98	2.72	2.54	2.18	1.91	1.52	1.19	0.54	0.34	0.19	1.14	131.0	142.2	3.20	1.19	0.71
.032	4.84	4.39	4.23	4.08	3.94	3.79	3.65	3.33	3.06	2.80	2.61	2.25	1.97	1.56	1.26	0.57	0.36	0.20	1.17	136.4	149.3	3.27	1.18	0.75
.034	4.96	4.50	4.34	4.18	4.03	3.88	3.74	3.41	3.14	2.88	2.68	2.29	2.03	1.61	1.32	0.60	0.38	0.21	1.19	141.8	156.2	3.34	1.17	0.80
.036	5.08	4.60	4.44	4.28	4.13	3.97	3.83	3.50	3.22	2.96	2.75	2.36	2.10	1.67	1.37	0.63	0.40	0.23	1.21	147.2	163.1	3.41	1.16	0.84
.038	5.19	4.71	4.54	4.38	4.23	4.07	3.92	3.59	3.30	3.03	2.82	2.42	2.15	1.72	1.42	0.66	0.42	0.24	1.24	152.6	169.8	3.47	1.15	0.88
.040	5.29	4.82	4.65	4.48	4.32	4.16	4.01	3.67	3.38	3.11	2.88	2.48	2.20	1.77	1.45	0.69	0.44	0.25	1.26	158.0	176.5	3.54	1.15	0.92
.042	5.40	4.93	4.75	4.58	4.42	4.26	4.10	3.76	3.46	3.19	2.95	2.55	2.27	1.81	1.50	0.72	0.46	0.26	1.28	163.4	183.1	3.61	1.14	0.97
.044	5.52	5.03	4.85	4.68	4.52	4.35	4.19	3.84	3.54	3.26	3.01	2.61	2.31	1.86	1.54	0.76	0.47	0.27	1.30	168.8	189.6	3.68	1.13	1.01
.046	5.63	5.14	4.96	4.78	4.61	4.45	4.28	3.93	3.61	3.34	3.08	2.67	2.36	1.92	1.59	0.78	0.49	0.28	1.32	174.2	196.1	3.75	1.12	1.05
.048	5.74	5.25	5.06	4.88	4.71	4.54	4.37	4.01	3.69	3.42	3.14	2.74	2.42	1.97	1.63	0.82	0.51	0.29	1.34	179.6	202.5	3.82	1.11	1.09
.050	5.85	5.35	5.17	4.97	4.81	4.63	4.46	4.10	3.77	3.49	3.21	2.80	2.49	2.02	1.66	0.84	0.53	0.31	1.36	185.0	208.8	3.89	1.10	1.14
.052	5.97	5.46	5.27	5.07	4.90	4.73	4.55	4.18	3.85	3.57	3.27	2.86	2.52	2.07	1.71	0.88	0.55	0.32	1.38	190.4	215.1	3.96	1.09	1.18
.054	6.09	5.57	5.37	5.17	5.00	4.82	4.64	4.27	3.92	3.64	3.34	2.92	2.58	2.11	1.75	0.91	0.57	0.33	1.40	195.8	221.4	4.03	1.08	1.22
.056	6.22	5.67	5.48	5.27	5.10	4.92	4.73	4.35	4.00	3.72	3.41	2.99	2.63	2.15	1.79	0.94	0.59	0.34	1.42	201.2	227.5	4.09	1.07	1.26
.058	6.34	5.78	5.58	5.37	5.19	5.01	4.82	4.44	4.08	3.79	3.49	3.05	2.69	2.20	1.84	0.97	0.61	0.35	1.44	206.6	233.7	4.16	1.07	1.31
.060	6.46	5.89	5.68	5.47	5.29	5.10	4.91	4.52	4.15	3.86	3.56	3.11	2.75	2.24	1.88	1.00	0.63	0.36	1.46	212.0	239.8	4.23	1.06	1.35
.062	6.58	5.99	5.79	5.57	5.39	5.20	5.00	4.61	4.23	3.94	3.63	3.17	2.80	2.29	1.91	1.02	0.65	0.37	1.47	217.4	245.9	4.30	1.05	1.39
.064	6.70	6.10	5.89	5.67	5.48	5.29	5.09	4.69	4.30	4.01	3.70	3.23	2.86	2.34	1.96	1.03	0.67	0.38	1.49	222.8	251.9	4.37	1.04	1.43
.066	6.82	6.21	6.00	5.77	5.58	5.38	5.18	4.77	4.38	4.09	3.77	3.30	2.91	2.38	2.00	1.04	0.69	0.39	1.51	228.2	257.9	4.44	1.03	1.48
.068	6.95	6.32	6.10	5.87	5.67	5.48	5.27	4.86	4.46	4.16	3.84	3.36	2.97	2.43	2.04	1.08	0.71	0.41	1.53	233.6	263.8	4.51	1.02	1.52
.070	7.07	6.42	6.20	5.97	5.77	5.57	5.36	4.94	4.53	4.23	3.91	3.42	3.03	2.48	2.08	1.12	0.73	0.42	1.55	239.0	269.8	4.58	1.01	1.56
.072	7.19	6.53	6.31	6.07	5.87	5.67	5.46	5.03	4.61	4.31	3.99	3.48	3.08	2.52	2.13	1.15	0.75	0.43	1.56	244.4	275.7	4.64	1.00	1.60
.074	7.31	6.64	6.41	6.18	5.96	5.76	5.55	5.11	4.68	4.38	4.06	3.54	3.14	2.57	2.16	1.16	0.77	0.44	1.58	249.8	281.6	4.71	1.00	1.65
.076	7.43	6.74	6.51	6.28	6.06	5.85	5.64	5.19	4.76	4.45	4.13	3.60	3.19	2.61	2.20	1.19	0.79	0.45	1.60	255.2	287.4	4.78	0.99	1.69
.078	7.55	6.85	6.62	6.38	6.15	5.95	5.73	5.28	4.83	4.53	4.20	3.66	3.25	2.66	2.25	1.21	0.81	0.46	1.61	260.6	293.2	4.85	0.98	1.73
.080	7.67	6.96	6.72	6.48	6.25	6.04	5.82	5.36	4.91	4.60	4.27	3.72	3.30	2.70	2.29	1.23	0.83	0.47	1.63	266.0	299.0	4.92	0.97	1.77

L/t_e	VALUES OF MOMENT MULTIPLIERS δ																			
	VALUES OF ULTIMATE STRESS P_u/A_g IN KSI																			
	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.03	1.04
3.0	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.06	1.07	1.08	1.09
4.0	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.05	1.08	1.09	1.11	1.12	1.13	1.15	1.16
5.0	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.08	1.13	1.16	1.18	1.20	1.23	1.25	1.28
6.0	1.01	1.01	1.02	1.03	1.04	1.05	1.05	1.06	1.07	1.08	1.09	1.10	1.10	1.11	1.12	1.21	1.24	1.28	1.32	1.37	1.41	1.46
7.0	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.11	1.12	1.14	1.15	1.16	1.18	1.30	1.36	1.42	1.49	1.57	1.66	1.76
8.0	1.01	1.03	1.04	1.05	1.07	1.08	1.10	1.12	1.13	1.15	1.17	1.18	1.20	1.22	1.24	1.43	1.53	1.64	1.76	1.91	2.08	2.28
9.0	1.02	1.03	1.05	1.07	1.09	1.11	1.13	1.15	1.17	1.20	1.22	1.25	1.27	1.30	1.33	1.62	1.78	1.97	2.21	2.51	2.91	3.46
10.0	1.02	1.04	1.06	1.09	1.11	1.14	1.17	1.19	1.22	1.25	1.29	1.32	1.36	1.40	1.44	1.90	2.18	2.55	3.08	3.89	5.28	8.20
11.0	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.32	1.37	1.42	1.47	1.52	1.58	2.34	2.89	3.78	5.47	9.91		
12.0	1.03	1.06	1.10	1.13	1.17	1.21	1.26	1.30	1.36	1.41	1.47	1.54	1.61	1.69	1.78	3.13	4.51	8.03				
13.0	1.04	1.07	1.11	1.16	1.21	1.26	1.32	1.38	1.45	1.52	1.60	1.70	1.80	1.92	2.06	4.98						
14.0	1.04	1.09	1.14	1.19	1.25	1.31	1.39	1.47	1.56	1.66	1.78	1.91	2.07	2.25	2.47							
15.0	1.05	1.10	1.16	1.22	1.30	1.38	1.47	1.57	1.70	1.84	2.01	2.21	2.46	2.76	3.16							
16.0	1.05	1.12	1.18	1.26	1.35	1.45	1.57	1.71	1.88	2.08	2.33	2.65	3.07	3.65	4.51							
17.0	1.06	1.13	1.21	1.31	1.41	1.54	1.69	1.88	2.11	2.41	2.81	3.36	4.19	5.55	8.23							
18.0	1.07	1.15	1.25	1.36	1.49	1.65	1.85	2.11	2.44	2.91	3.60	4.71	6.83									

p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .75																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	VALUES OF ECCENTRICITY RATIO $\delta e/t$																							
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	3.53	3.20	3.08	2.96	2.84	2.73	2.62	2.37	2.14	1.95	1.77	1.46	1.23	0.82	0.58	0.21	0.13	0.07	1.00	92.2	76.0	2.71	1.43	0.29
.012	3.65	3.31	3.19	3.07	2.95	2.83	2.73	2.47	2.24	2.05	1.88	1.57	1.34	0.94	0.67	0.25	0.16	0.09	1.00	100.6	88.5	2.78	1.43	0.35
.014	3.78	3.42	3.29	3.17	3.05	2.93	2.83	2.56	2.34	2.13	1.97	1.66	1.41	1.04	0.75	0.29	0.18	0.10	1.04	109.1	100.4	2.85	1.42	0.40
.016	3.90	3.53	3.40	3.28	3.16	3.03	2.93	2.65	2.43	2.21	2.06	1.75	1.50	1.14	0.84	0.33	0.20	0.11	1.08	117.5	112.1	2.92	1.42	0.46
.018	4.03	3.65	3.51	3.38	3.26	3.14	3.02	2.75	2.53	2.30	2.14	1.83	1.59	1.23	0.93	0.37	0.23	0.13	1.12	125.9	123.4	2.99	1.42	0.51
.020	4.15	3.76	3.62	3.49	3.37	3.24	3.12	2.85	2.62	2.40	2.22	1.92	1.67	1.31	1.01	0.41	0.25	0.14	1.16	134.4	134.4	3.06	1.41	0.56
.022	4.27	3.87	3.73	3.59	3.47	3.34	3.22	2.95	2.70	2.49	2.30	1.98	1.74	1.36	1.08	0.44	0.27	0.15	1.20	142.8	145.2	3.13	1.41	0.62
.024	4.37	3.98	3.84	3.70	3.57	3.44	3.31	3.04	2.79	2.58	2.37	2.05	1.81	1.40	1.16	0.48	0.30	0.17	1.23	151.2	155.8	3.20	1.41	0.67
.026	4.47	4.09	3.95	3.80	3.67	3.54	3.41	3.13	2.87	2.66	2.44	2.13	1.87	1.46	1.23	0.52	0.32	0.18	1.26	159.7	166.2	3.27	1.40	0.73
.028	4.58	4.20	4.05	3.91	3.77	3.64	3.51	3.23	2.95	2.75	2.53	2.20	1.96	1.54	1.29	0.56	0.34	0.19	1.30	168.1	176.5	3.33	1.40	0.78
030	4.71	4.31	4.16	4.01	3.87	3.74	3.61	3.32	3.03	2.83	2.61	2.27	2.00	1.61	1.33	0.59	0.37	0.21	1.33	176.6	186.6	3.40	1.40	0.83
.032	4.83	4.42	4.27	4.12	3.97	3.84	3.71	3.41	3.12	2.91	2.70	2.34	2.07	1.68	1.36	0.63	0.39	0.22	1.36	185.0	196.6	3.47	1.39	0.89
.034	4.95	4.53	4.38	4.22	4.07	3.94	3.80	3.50	3.21	2.99	2.78	2.41	2.13	1.74	1.38	0.67	0.41	0.23	1.39	193.4	206.5	3.54	1.39	0.94
.036	5.07	4.63	4.48	4.33	4.17	4.04	3.90	3.59	3.30	3.07	2.86	2.48	2.20	1.80	1.44	0.70	0.44	0.25	1.42	201.9	216.3	3.61	1.39	0.99
.038	5.20	4.75	4.59	4.43	4.27	4.14	4.00	3.68	3.39	3.15	2.94	2.55	2.26	1.85	1.51	0.74	0.46	0.26	1.45	210.3	226.0	3.68	1.38	1.05
.040	5.32	4.86	4.70	4.54	4.37	4.23	4.09	3.76	3.47	3.22	3.01	2.61	2.33	1.90	1.57	0.78	0.48	0.27	1.48	218.8	235.5	3.75	1.38	1.10
.042	5.45	4.98	4.80	4.64	4.47	4.33	4.19	3.85	3.56	3.30	3.09	2.70	2.39	1.95	1.63	0.82	0.51	0.29	1.51	227.2	245.1	3.82	1.38	1.15
.044	5.57	5.09	4.91	4.74	4.58	4.43	4.29	3.94	3.65	3.38	3.13	2.76	2.45	2.00	1.69	0.85	0.53	0.30	1.54	235.6	254.5	3.88	1.38	1.21
.046	5.69	5.21	5.01	4.85	4.68	4.53	4.38	4.03	3.73	3.45	3.20	2.82	2.52	2.05	1.74	0.89	0.55	0.31	1.56	244.1	263.9	3.95	1.37	1.26
.048	5.82	5.32	5.12	4.95	4.78	4.62	4.48	4.11	3.82	3.53	3.28	2.87	2.58	2.10	1.77	0.92	0.58	0.33	1.59	252.5	273.2	4.02	1.37	1.31
.050	5.94	5.43	5.23	5.06	4.88	4.72	4.57	4.20	3.90	3.60	3.35	2.95	2.64	2.15	1.82	0.96	0.60	0.34	1.62	260.9	282.4	4.09	1.37	1.37
.052	6.06	5.55	5.33	5.16	4.98	4.81	4.67	4.29	3.99	3.67	3.47	3.02	2.70	2.20	1.86	0.99	0.62	0.35	1.64	269.4	291.6	4.16	1.36	1.42
.054	6.18	5.66	5.44	5.26	5.08	4.91	4.76	4.37	4.07	3.75	3.54	3.09	2.76	2.25	1.91	1.03	0.65	0.37	1.67	277.8	300.7	4.23	1.36	1.47
.056	6.31	5.77	5.54	5.37	5.19	5.01	4.86	4.46	4.15	3.83	3.61	3.17	2.82	2.31	1.95	1.05	0.67	0.38	1.69	286.3	309.8	4.30	1.36	1.53
.058	6.43	5.89	5.65	5.47	5.29	5.10	4.95	4.55	4.24	3.91	3.69	3.24	2.88	2.36	2.00	1.09	0.69	0.39	1.72	294.7	318.9	4.37	1.35	1.58
.060	6.55	6.00	5.76	5.57	5.39	5.20	5.04	4.64	4.32	3.99	3.76	3.27	2.94	2.41	2.04	1.12	0.72	0.41	1.74	303.1	327.9	4.44	1.35	1.64
.062	6.68	6.11	5.87	5.68	5.49	5.30	5.14	4.73	4.40	4.08	3.83	3.34	3.00	2.47	2.08	1.15	0.74	0.42	1.77	311.6	336.9	4.50	1.35	1.69
.064	6.80	6.22	5.98	5.78	5.59	5.39	5.23	4.82	4.49	4.16	3.90	3.40	3.06	2.52	2.14	1.19	0.76	0.43	1.79	320.0	345.8	4.57	1.34	1.74
.066	6.93	6.34	6.09	5.88	5.69	5.49	5.33	4.91	4.57	4.24	3.97	3.47	3.12	2.57	2.18	1.22	0.79	0.45	1.81	328.4	354.7	4.64	1.34	1.80
.068	7.05	6.45	6.20	5.99	5.79	5.59	5.42	5.00	4.65	4.32	4.04	3.54	3.17	2.60	2.21	1.25	0.81	0.46	1.84	336.9	363.5	4.71	1.34	1.85
.070	7.17	6.56	6.31	6.09	5.89	5.69	5.51	5.09	4.73	4.40	4.11	3.60	3.23	2.65	2.26	1.26	0.83	0.47	1.86	345.3	372.4	4.78	1.33	1.90
.072	7.29	6.67	6.42	6.19	5.99	5.79	5.61	5.18	4.82	4.48	4.18	3.67	3.29	2.70	2.30	1.27	0.86	0.49	1.88	353.7	381.2	4.85	1.33	1.96
.074	7.42	6.78	6.53	6.29	6.09	5.89	5.70	5.27	4.90	4.56	4.25	3.74	3.36	2.76	2.34	1.28	0.88	0.50	1.90	362.2	389.9	4.92	1.33	2.01
.076	7.54	6.90	6.64	6.40	6.19	5.99	5.79	5.36	4.98	4.64	4.32	3.80	3.42	2.81	2.38	1.29	0.90	0.51	1.93	370.6	398.7	4.99	1.32	2.06
.078	7.66	7.00	6.74	6.50	6.29	6.08	5.88	5.45	5.06	4.72	4.39	3.87	3.47	2.86	2.43	1.29	0.92	0.53	1.95	379.1	407.4	5.05	1.32	2.12
.080	7.79	7.11	6.85	6.60	6.39	6.18	5.98	5.54	5.14	4.80	4.46	3.93	3.52	2.91	2.47	1.30	0.94	0.54	1.97	387.5	416.1	5.12	1.32	2.17

p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .9																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	VALUES OF ECCENTRICITY RATIO $\delta e/t$																							
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	3.54	3.20	3.07	2.95	2.84	2.72	2.62	2.37	2.15	1.96	1.80	1.48	1.23	0.83	0.59	0.23	0.14	0.08	1.05	110.8	94.3	2.92	1.55	0.33
.012	3.68	3.31	3.19	3.07	2.95	2.83	2.73	2.47	2.26	2.06	1.91	1.59	1.35	0.96	0.70	0.27	0.16	0.09	1.11	122.9	110.3	2.99	1.55	0.39
.014	3.81	3.43	3.30	3.18	3.06	2.94	2.83	2.58	2.36	2.16	2.00	1.72	1.45	1.05	0.79	0.31	0.19	0.11	1.16	135.1	125.9	3.06	1.55	0.46
.016	3.92	3.55	3.42	3.29	3.17	3.06	2.94	2.69	2.46	2.27	2.09	1.80	1.53	1.17	0.87	0.36	0.22	0.12	1.21	147.2	141.1	3.12	1.54	0.52
018	4.02	3.66	3.53	3.40	3.28	3.16	3.04	2.79	2.55	2.36	2.17	1.88	1.65	1.26	0.96	0.40	0.24	0.14	1.26	159.4	156.0	3.19	1.54	0.59
.020	4.13	3.78	3.65	3.51	3.39	3.27	3.15	2.89	2.64	2.46	2.27	1.97	1.73	1.34	1.04	0.44	0.27	0.15	1.31	171.5	170.6	3.26	1.54	0.65
.022	4.25	3.89	3.76	3.62	3.49	3.38	3.26	2.99	2.74	2.55	2.36	2.05	1.81	1.41	1.13	0.48	0.30	0.17	1.36	183.6	185.0	3.33	1.53	0.72
.024	4.38	4.00	3.87	3.73	3.60	3.48	3.36	3.09	2.84	2.64	2.45	2.13	1.88	1.47	1.21	0.52	0.32	0.18	1.40	195.8	199.1	3.40	1.53	0.78
.026	4.50	4.13	3.98	3.84	3.70	3.58	3.47	3.18	2.94	2.72	2.54	2.22	1.96	1.52	1.28	0.56	0.35	0.20	1.44	207.9	213.1	3.47	1.53	0.84
.028	4.63	4.25	4.09	3.95	3.81	3.69	3.57	3.27	3.03	2.80	2.63	2.28	2.03	1.62	1.34	0.60	0.38	0.21	1.48	220.1	227.0	3.54	1.52	0.91
.030	4.75	4.37	4.20	4.06	3.92	3.79	3.67	3.36	3.13	2.88	2.71	2.35	2.10	1.72	1.39	0.64	0.40	0.23	1.52	232.2	240.7	3.61	1.52	0.97
.032	4.88	4.49	4.31	4.17	4.03	3.89	3.77	3.46	3.22	2.97	2.79	2.44	2.17	1.77	1.43	0.68	0.43	0.24	1.56	244.4	254.2	3.67	1.52	1.04
.034	5.00	4.61	4.42	4.28	4.13	3.99	3.87	3.56	3.31	3.06	2.87	2.52	2.24	1.83	1.47	0.73	0.45	0.26	1.60	256.5	267.7	3.74	1.52	1.10
036	5.13	4.73	4.53	4.38	4.24	4.09	3.97	3.66	3.40	3.15	2.94	2.57	2.30	1.89	1.51	0.76	0.48	0.27	1.64	268.7	281.0	3.81	1.51	1.17
.038	5.25	4.84	4.65	4.49	4.35	4.20	4.06	3.75	3.48	3.24	3.02	2.64	2.37	1.95	1.59	0.80	0.50	0.29	1.68	280.8	294.2	3.88	1.51	1.23
.040	5.37	4.96	4.77	4.60	4.45	4.30	4.16	3.85	3.57	3.33	3.09	2.72	2.44	2.01	1.69	0.84	0.53	0.30	1.71	293.0	307.4	3.95	1.51	1.30
042	5.50	5.08	4.88	4.70	4.55	4.40	4.26	3.94	3.66	3.41	3.16	2.79	2.49	2.05	1.74	0.88	0.56	0.32	1.75	305.2	320.4	4.02	1.50	1.36
.044	5.62	5.18	5.00	4.81	4.66	4.51	4.35	4.04	3.74	3.50	3.24	2.86	2.56	2.11	1.79	0.92	0.58	0.33	1.78	317.3	333.4	4.09	1.50	1.43
.046	5.75	5.28	5.11	4.91	4.76	4.61	4.45	4.13	3.83	3.58	3.33	2.94	2.64	2.17	1.84	0.95	0.61	0.35	1.82	329.5	346.4	4.16	1.50	1.49
.048	5.87	5.38	5.22	5.02	4.87	4.71	4.55	4.23	3.91	3.67	3.41	3.01	2.68	2.22	1.89	0.99	0.63	0.36	1.85	341.6	359.2	4.23	1.49	1.56
050	6.00	5.49	5.34	5.13	4.97	4.81	4.66	4.32	3.99	3.75	3.49	3.08	2.75	2.28	1.95	1.03	0.66	0.37	1.88	353.7	372.0	4.29	1.49	1.62
.052	6.12	5.59	5.45	5.24	5.07	4.92	4.76	4.41	4.08	3.83	3.58	3.15	2.81	[illegible]	[illegible]	1.06	0.68	0.39	1.91	365.9	384.7	4.36	1.49	1.69
.054	6.25	5.70	5.56	5.35	5.17	5.02	4.86	4.51	4.17	3.91	3.66	3.22	2.88	[illegible]	[illegible]	1.10	0.71	0.40	1.94	378.0	397.4	4.43	1.48	1.75
.056	6.37	5.82	5.68	5.47	5.28	5.12	4.96	4.60	4.26	3.99	3.74	3.29	2.95	2.44	[illegible]	1.13	0.73	0.42	1.98	390.2	410.1	4.50	1.48	1.81
.058	6.49	5.93	5.79	5.58	5.38	5.22	5.05	4.69	4.35	4.08	3.82	3.36	3.01	2.50	[illegible]	1.17	0.75	0.43	2.01	402.3	422.6	4.57	1.48	1.88
.060	6.62	6.05	5.90	5.69	5.48	5.32	5.15	4.78	4.44	4.16	3.90	3.43	3.08	2.55	[illegible]	1.20	0.78	0.45	2.04	414.5	435.2	4.64	1.47	1.94
.062	6.74	6.16	6.00	5.80	5.58	5.42	5.25	4.87	4.53	4.24	3.98	3.50	3.14	2.61	2.22	1.24	0.80	0.46	2.07	426.7	447.7	4.71	1.47	2.01
.064	6.87	6.27	6.10	5.91	5.68	5.52	5.35	4.96	4.61	4.31	4.06	3.60	3.20	2.66	2.27	1.27	0.83	0.48	2.09	438.8	460.2	4.78	1.47	2.07
.066	6.99	6.39	6.20	6.01	5.79	5.62	5.45	5.05	4.70	4.39	4.14	3.66	3.27	2.71	2.32	1.29	0.85	0.49	2.12	451.0	472.6	4.84	1.46	2.14
.068	7.12	6.50	6.30	6.12	5.90	5.72	5.55	5.14	4.79	4.47	4.22	3.73	3.33	2.78	2.37	1.31	0.88	0.51	2.15	463.1	485.0	4.91	1.46	2.20
070	7.24	6.61	6.40	6.23	6.00	5.82	5.65	5.23	4.88	4.55	4.29	3.79	3.40	2.83	2.42	1.33	0.90	0.52	2.18	475.2	497.4	4.98	1.46	2.27
.072	7.37	6.73	6.50	6.34	6.11	5.92	5.74	5.32	4.97	4.63	4.37	3.85	3.46	2.88	2.45	1.34	0.93	0.53	2.21	487.4	509.7	5.05	1.45	2.33
.074	7.49	6.84	6.61	6.45	6.22	6.01	5.84	5.41	5.05	4.71	4.45	3.92	3.52	2.94	2.50	1.36	0.95	0.55	2.24	499.5	522.0	5.12	1.45	2.40
.076	7.62	6.95	6.72	6.56	6.32	6.11	5.94	5.50	5.14	4.78	4.53	3.98	3.59	2.98	2.54	1.37	0.97	0.56	2.26	511.7	534.3	5.19	1.45	2.46
.078	7.74	7.06	6.83	6.66	6.43	6.21	6.04	5.59	5.23	4.86	4.60	4.04	3.65	3.02	2.59	1.38	0.99	0.58	2.29	523.8	546.6	5.26	1.45	2.53
.080	7.87	7.18	6.94	6.77	6.54	6.31	6.13	5.68	5.32	4.94	4.68	4.12	3.71	3.08	2.64	1.39	1.02	0.59	2.32	536.0	558.8	5.33	1.44	2.59

Table 6.6A.5 Values of ultimate axial stress, P_u/A_g, for rectangular column with symmetric reinforcing steel, $f'_c = 4$ ksi, $f_{dy} = 72$ ksi, $\gamma = 0.45, 0.60, 0.75, 0.90$



P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .45$ — VALUES OF ECCENTRICITY RATIO $\delta e/t$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
.010	4.50	4.14	4.00	3.86	3.71	3.57	3.43	3.09	2.75	2.44	2.19	1.74	1.39	0.92	0.65	0.25	0.15	0.09	1.00	81.9	52.7	2.95	1.43	0.29
.012	4.61	4.24	4.10	3.95	3.80	3.66	3.52	3.17	2.82	2.51	2.25	1.80	1.47	1.00	0.71	0.28	0.17	0.10	1.00	84.9	60.6	3.01	1.39	0.33
.014	4.73	4.35	4.19	4.04	3.89	3.75	3.60	3.25	2.89	2.58	2.31	1.88	1.55	1.09	0.78	0.31	0.19	0.11	1.00	87.9	68.0	3.08	1.36	0.37
.016	4.84	4.45	4.29	4.14	3.98	3.83	3.68	3.32	2.96	2.65	2.37	1.91	1.61	1.15	0.84	0.34	0.21	0.12	1.00	91.0	75.1	3.14	1.33	0.40
.018	4.96	4.55	4.39	4.23	4.07	3.92	3.77	3.40	3.02	2.71	2.42	1.97	1.67	1.20	0.91	0.37	0.23	0.13	1.00	94.0	81.8	3.21	1.29	0.44
.020	5.07	4.65	4.49	4.32	4.16	4.00	3.85	3.48	3.09	2.78	2.47	2.03	1.71	1.25	0.97	0.40	0.25	0.14	1.00	97.0	88.3	3.27	1.26	0.48
.022	5.19	4.75	4.59	4.42	4.25	4.09	3.93	3.55	3.16	2.84	2.52	2.08	1.75	1.32	1.01	0.42	0.27	0.15	1.00	100.1	94.5	3.34	1.23	0.51
.024	5.30	4.85	4.68	4.51	4.34	4.18	4.01	3.63	3.22	2.91	2.58	2.14	1.81	1.36	1.07	0.45	0.28	0.16	1.00	103.1	100.6	3.41	1.19	0.54
.026	5.41	4.96	4.78	4.61	4.43	4.26	4.10	3.71	3.29	2.98	2.64	2.19	1.84	1.40	1.10	0.48	0.30	0.17	1.00	106.2	106.4	3.47	1.16	0.58
028	5.53	5.06	4.88	4.70	4.52	4.35	4.18	3.78	3.35	3.04	2.70	2.25	1.89	1.45	1.14	0.50	0.32	0.18	1.00	109.2	112.0	3.54	1.12	0.61
.030	5.64	5.16	4.98	4.79	4.61	4.44	4.26	3.86	3.42	3.11	2.77	2.30	1.94	1.49	1.19	0.53	0.33	0.19	1.00	112.2	117.5	3.60	1.09	0.65
.032	5.76	5.26	5.07	4.89	4.70	4.52	4.35	3.94	3.49	3.17	2.83	2.35	1.99	1.52	1.22	0.56	0.35	0.20	1.00	115.3	122.9	3.67	1.06	0.68
.034	5.87	5.36	5.17	4.98	4.78	4.61	4.43	4.01	3.55	3.23	2.89	2.41	2.04	1.56	1.26	0.58	0.36	0.21	1.00	118.3	128.1	3.73	1.02	0.71
.036	5.99	5.47	5.27	5.07	4.87	4.70	4.51	4.09	3.62	3.30	2.96	2.46	2.09	1.59	1.29	0.60	0.38	0.22	1.00	121.3	133.2	3.80	0.99	0.74
.038	6.10	5.57	5.37	5.17	4.96	4.78	4.60	4.17	3.69	3.36	3.02	2.51	2.13	1.63	1.32	0.63	0.40	0.23	1.00	124.4	138.2	3.87	0.96	0.78
.040	6.22	5.67	5.47	5.26	5.05	4.87	4.68	4.24	3.76	3.43	3.08	2.56	2.15	1.66	1.35	0.65	0.41	0.24	1.00	127.4	143.1	3.93	0.92	0.81
.042	6.33	5.77	5.56	5.36	5.14	4.95	4.76	4.32	3.82	3.49	3.14	2.58	2.20	1.70	1.38	0.68	0.43	0.25	1.00	130.5	147.9	4.00	0.89	0.84
.064	6.45	5.87	5.66	5.45	5.23	5.04	4.84	4.39	3.89	3.55	3.14	2.63	2.24	1.72	1.41	0.70	0.45	0.26	1.00	133.5	152.6	4.06	0.85	0.87
.046	6.56	5.98	5.76	5.54	5.32	5.13	4.93	4.47	3.96	3.62	3.20	2.68	2.29	1.76	1.44	0.73	0.46	0.27	1.01	136.5	157.2	4.13	0.82	0.91
048	6.68	6.08	5.86	5.64	5.41	5.21	5.01	4.55	4.03	3.68	3.26	2.73	2.33	1.79	1.47	0.75	0.48	0.27	1.02	139.6	161.8	4.19	0.79	0.94
.050	6.79	6.18	5.95	5.73	5.50	5.30	5.09	4.62	4.10	3.68	3.31	2.78	2.38	1.83	1.50	0.76	0.49	0.28	1.03	142.6	166.2	4.26	0.75	0.97
.052	6.91	6.28	6.05	5.82	5.59	5.39	5.18	4.70	4.17	3.74	3.37	2.85	2.42	1.87	1.52	0.78	0.51	0.29	1.05	145.6	170.7	4.32	0.72	1.00
.054	7.02	6.38	6.15	5.92	5.68	5.47	5.26	4.78	4.24	3.80	3.43	2.90	2.47	1.91	1.55	0.80	0.52	0.30	1.06	148.7	175.0	4.39	0.69	1.03
.056	7.14	6.49	6.25	6.01	5.77	5.56	5.34	4.85	4.31	3.86	3.48	2.94	2.51	1.93	1.58	0.82	0.54	0.31	1.07	151.7	179.3	4.46	0.65	1.06
.058	7.25	6.59	6.35	6.11	5.86	5.65	5.43	4.93	4.37	3.92	3.54	2.99	2.56	1.96	1.61	0.83	0.56	0.32	1.08	154.8	183.6	4.52	0.62	1.10
.060	7.37	6.69	6.44	6.20	5.95	5.73	5.51	5.00	4.44	3.99	3.60	3.04	2.60	2.00	1.64	0.85	0.57	0.33	1.09	157.8	187.7	4.59	0.59	1.13
.062	7.48	6.79	6.54	6.29	6.04	5.82	5.59	5.08	4.51	4.05	3.65	3.08	2.62	2.03	1.67	0.86	0.58	0.34	1.10	160.8	191.9	4.65	0.55	1.16
.064	7.60	6.90	6.64	6.39	6.13	5.90	5.68	5.16	4.58	4.11	3.71	3.13	2.66	2.07	1.68	0.88	0.59	0.35	1.11	163.9	196.0	4.72	0.52	1.19
.066	7.71	7.00	6.74	6.48	6.22	5.99	5.76	5.23	4.65	4.17	3.77	3.17	2.71	2.10	1.71	0.89	0.60	0.36	1.12	166.9	200.0	4.78	0.48	1.22
.068	7.83	7.10	6.83	6.57	6.31	6.08	5.84	5.31	4.72	4.23	3.82	3.22	2.75	2.14	1.74	0.91	0.61	0.37	1.13	169.9	204.1	4.85	0.45	1.25
.070	7.94	7.20	6.93	6.67	6.39	6.16	5.92	5.39	4.79	4.29	3.88	3.26	2.79	2.17	1.77	0.93	0.63	0.38	1.14	173.0	208.0	4.91	0.42	1.29
.072	8.06	7.30	7.03	6.76	6.48	6.25	6.01	5.46	4.86	4.35	3.94	3.31	2.84	2.19	1.80	0.94	0.63	0.38	1.15	176.0	212.0	4.98	0.38	1.32
.074	8.17	7.41	7.13	6.86	6.57	6.34	6.09	5.54	4.92	4.42	3.99	3.37	2.88	2.23	1.83	0.95	0.64	0.39	1.16	179.1	215.9	5.05	0.35	1.35
076	8.29	7.51	7.23	6.95	6.66	6.42	6.17	5.61	4.99	4.48	4.05	3.41	2.92	2.26	1.84	0.96	0.65	0.40	1.17	182.1	219.7	5.11	0.32	1.38
.078	8.40	7.61	7.32	7.04	6.75	6.51	6.26	5.69	5.06	4.54	4.11	3.45	2.96	2.29	1.87	0.98	0.66	0.40	1.18	185.1	223.6	5.18	0.28	1.41
.080	8.52	7.71	7.42	7.14	6.84	6.60	6.34	5.77	5.13	4.60	4.16	3.49	3.01	2.33	1.90	0.99	0.67	0.41	1.19	188.2	227.4	5.24	0.25	1.44

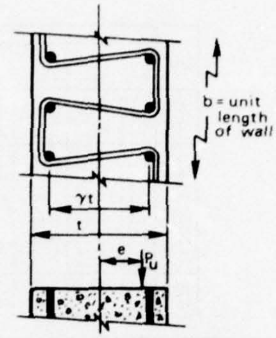
P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .6$ — VALUES OF ECCENTRICITY RATIO $\delta e/t$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
.010	4.48	4.10	3.95	3.80	3.65	3.50	3.36	3.02	2.71	2.44	2.21	1.79	1.40	0.88	0.61	0.23	0.14	0.08	1.00	93.7	64.6	3.23	1.71	0.29
.012	4.60	4.20	4.05	3.90	3.74	3.60	3.45	3.11	2.80	2.53	2.29	1.91	1.53	0.98	0.69	0.26	0.16	0.09	1.00	99.1	74.8	3.30	1.70	0.34
.014	4.72	4.31	4.15	4.00	3.84	3.69	3.55	3.20	2.88	2.62	2.36	1.97	1.62	1.09	0.78	0.30	0.18	0.10	1.00	104.5	84.6	3.36	1.69	0.38
.016	4.84	4.41	4.25	4.09	3.94	3.79	3.64	3.29	2.96	2.71	2.44	2.05	1.71	1.19	0.85	0.33	0.21	0.12	1.00	109.9	93.9	3.43	1.68	0.43
.018	4.96	4.52	4.35	4.19	4.03	3.88	3.73	3.38	3.05	2.79	2.53	2.14	1.83	1.27	0.92	0.37	0.23	0.13	1.00	115.3	103.0	3.50	1.67	0.47
.020	5.08	4.62	4.46	4.29	4.13	3.97	3.82	3.46	3.14	2.87	2.62	2.22	1.89	1.37	1.00	0.40	0.25	0.14	1.00	120.7	111.8	3.57	1.66	0.52
.022	5.19	4.73	4.56	4.39	4.22	4.06	3.91	3.55	3.22	2.95	2.70	2.29	1.96	1.45	1.08	0.43	0.27	0.15	1.00	126.1	120.3	3.64	1.65	0.56
.024	5.31	4.83	4.66	4.49	4.32	4.16	4.00	3.63	3.30	3.02	2.78	2.36	2.03	1.52	1.14	0.46	0.29	0.16	1.00	131.5	128.6	3.70	1.64	0.60
.026	5.43	4.94	4.76	4.59	4.42	4.25	4.09	3.71	3.39	3.10	2.86	2.43	2.10	1.58	1.21	0.50	0.31	0.17	1.01	136.9	136.7	3.77	1.63	0.65
.028	5.55	5.05	4.86	4.69	4.51	4.34	4.19	3.80	3.47	3.17	2.94	2.49	2.18	1.63	1.29	0.53	0.33	0.19	1.03	142.3	144.6	3.84	1.62	0.69
.030	5.67	5.15	4.96	4.79	4.61	4.43	4.28	3.88	3.55	3.24	3.01	2.57	2.22	1.72	1.36	0.56	0.35	0.20	1.05	147.7	152.4	3.91	1.61	0.73
.032	5.79	5.26	5.06	4.89	4.70	4.52	4.37	3.96	3.63	3.31	3.09	2.63	2.29	1.79	1.42	0.59	0.37	0.21	1.07	153.1	160.0	3.97	1.60	0.78
.034	5.90	5.36	5.17	4.98	4.80	4.61	4.46	4.04	3.72	3.39	3.16	2.68	2.35	1.84	1.46	0.62	0.39	0.22	1.09	158.5	167.5	4.04	1.59	0.82
.036	6.02	5.47	5.27	5.08	4.90	4.71	4.54	4.13	3.80	3.45	3.23	2.74	2.41	1.90	1.51	0.65	0.41	0.23	1.11	163.9	174.8	4.11	1.58	0.86
.038	6.14	5.57	5.37	5.18	4.99	4.80	4.63	4.21	3.88	3.53	3.30	2.82	2.47	1.96	1.54	0.69	0.43	0.24	1.13	169.3	182.1	4.18	1.57	0.90
.040	6.26	5.68	5.47	5.28	5.09	4.89	4.72	4.30	3.96	3.61	3.37	2.89	2.53	2.00	1.58	0.72	0.45	0.26	1.14	174.7	189.2	4.25	1.56	0.95
.042	6.38	5.78	5.57	5.38	5.18	4.99	4.81	4.38	4.03	3.68	3.44	2.96	2.59	2.05	1.66	0.75	0.47	0.27	1.16	180.1	196.3	4.31	1.55	0.99
.044	6.49	5.89	5.68	5.48	5.28	5.08	4.90	4.47	4.11	3.76	3.51	2.99	2.65	2.10	1.73	0.78	0.49	0.28	1.18	185.5	203.2	4.38	1.54	1.03
.046	6.61	6.00	5.78	5.57	5.38	5.17	4.99	4.55	4.19	3.84	3.57	3.06	2.70	2.15	1.77	0.81	0.51	0.29	1.20	190.9	210.1	4.45	1.54	1.08
048	6.73	6.10	5.88	5.67	5.47	5.26	5.08	4.64	4.27	3.92	3.64	3.12	2.78	2.21	1.82	0.84	0.53	0.30	1.21	196.3	216.9	4.52	1.53	1.12
.050	6.84	6.21	5.98	5.77	5.57	5.36	5.17	4.72	4.35	3.99	3.71	3.18	2.83	2.26	1.86	0.87	0.55	0.31	1.23	201.7	223.7	4.58	1.52	1.16
.052	6.95	6.31	6.09	5.87	5.66	5.45	5.26	4.80	4.42	4.07	3.77	3.25	2.88	2.31	1.90	0.90	0.57	0.32	1.25	207.1	230.3	4.65	1.51	1.20
.054	7.06	6.42	6.19	5.97	5.76	5.54	5.34	4.89	4.50	4.14	3.84	3.31	2.93	2.35	1.94	0.93	0.59	0.34	1.26	212.5	236.9	4.72	1.50	1.25
.056	7.17	6.52	6.29	6.06	5.85	5.64	5.43	4.97	4.58	4.22	3.90	3.37	3.00	2.40	1.98	0.96	0.61	0.35	1.28	217.9	243.5	4.79	1.49	1.29
.058	7.28	6.63	6.39	6.16	5.95	5.73	5.52	5.06	4.66	4.30	3.97	3.43	3.04	2.45	2.03	0.99	0.62	0.36	1.29	223.3	249.9	4.85	1.48	1.33
.060	7.39	6.73	6.49	6.26	6.04	5.82	5.61	5.14	4.73	4.37	4.03	3.50	3.08	2.50	2.07	1.02	0.64	0.37	1.31	228.7	256.4	4.92	1.47	1.37
.062	7.50	6.84	6.60	6.36	6.14	5.91	5.70	5.23	4.81	4.44	4.09	3.56	3.14	2.56	2.12	1.06	0.66	0.38	1.32	234.1	262.8	4.99	1.46	1.42
.064	7.61	6.95	6.70	6.45	6.23	6.01	5.78	5.31	4.89	4.52	4.16	3.62	3.21	2.61	2.16	1.09	0.68	0.39	1.34	239.5	269.1	5.06	1.45	1.46
.066	7.72	7.05	6.80	6.55	6.33	6.10	5.87	5.39	4.96	4.59	4.22	3.68	3.27	2.65	2.19	1.11	0.70	0.40	1.36	244.9	275.4	5.13	1.44	1.50
.068	7.83	7.16	6.90	6.65	6.42	6.19	5.96	5.48	5.04	4.67	4.28	3.75	3.30	2.70	2.23	1.15	0.72	0.41	1.37	250.3	281.6	5.19	1.43	1.54
.070	7.94	7.26	7.01	6.75	6.52	6.28	6.05	5.56	5.11	4.74	4.35	3.81	3.35	2.75	2.27	1.18	0.74	0.43	1.38	255.7	287.8	5.26	1.42	1.59
.072	8.06	7.37	7.11	6.84	6.61	6.38	6.13	5.64	5.19	4.82	4.42	3.87	3.41	2.78	2.32	1.21	0.76	0.44	1.40	261.1	294.0	5.33	1.41	1.63
.074	8.18	7.47	7.21	6.94	6.71	6.47	6.22	5.73	5.26	4.89	4.49	3.93	3.46	2.83	2.36	1.24	0.78	0.45	1.41	266.5	300.1	5.40	1.40	1.67
.076	8.30	7.58	7.31	7.04	6.80	6.56	6.31	5.81	5.34	4.96	4.56	3.99	3.52	2.88	2.40	1.27	0.80	0.46	1.43	271.9	306.2	5.46	1.39	1.71
.078	8.42	7.68	7.41	7.14	6.90	6.65	6.40	5.89	5.41	5.04	4.63	4.05	3.58	2.92	2.45	1.30	0.82	0.47	1.44	277.3	312.3	5.53	1.38	1.75
.080	8.54	7.79	7.52	7.23	6.99	6.75	6.49	5.98	5.49	5.11	4.70	4.11	3.63	2.97	2.48	1.32	0.84	0.48	1.46	282.7	318.3	5.60	1.37	1.80

L/t_e	VALUES OF MOMENT MULTIPLIERS δ — VALUES OF ULTIMATE STRESS P_u/A_g IN KSI																			
	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03
3.0	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.04	1.04	1.05	1.05	1.06	1.06
4.0	1.00	1.00	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.06	1.07	1.08	1.09	1.10	1.11	1.12
5.0	1.00	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.04	1.04	1.04	1.05	1.05	1.06	1.06	1.10	1.11	1.13	1.15	1.16	1.18	1.20
6.0	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.08	1.09	1.15	1.17	1.20	1.22	1.25	1.28	1.31
7.0	1.01	1.02	1.02	1.03	1.04	1.05	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.21	1.25	1.29	1.33	1.38	1.42	1.48
8.0	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.10	1.11	1.12	1.13	1.14	1.16	1.17	1.29	1.35	1.41	1.48	1.55	1.64	1.73
9.0	1.01	1.03	1.04	1.05	1.07	1.08	1.09	1.11	1.12	1.14	1.16	1.17	1.19	1.21	1.23	1.40	1.49	1.59	1.70	1.82	1.97	2.14
10.0	1.02	1.03	1.05	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.25	1.27	1.30	1.55	1.68	1.84	2.03	2.26	2.55	2.93
11.0	1.02	1.04	1.06	1.08	1.10	1.12	1.15	1.17	1.20	1.23	1.25	1.28	1.31	1.35	1.38	1.75	1.96	2.23	2.58	3.07	3.78	4.92
12.0	1.02	1.05	1.07	1.10	1.12	1.15	1.18	1.21	1.25	1.28	1.32	1.36	1.40	1.44	1.49	2.04	2.40	2.91	3.70	5.06	8.03	
13.0	1.03	1.05	1.08	1.11	1.15	1.18	1.22	1.26	1.30	1.35	1.39	1.45	1.50	1.56	1.63	2.50	3.17	4.36	6.95			
14.0	1.03	1.06	1.10	1.14	1.18	1.22	1.26	1.31	1.37	1.42	1.49	1.56	1.63	1.72	1.81	3.28	4.86	9.40				
15.0	1.04	1.07	1.11	1.16	1.21	1.26	1.31	1.38	1.44	1.52	1.60	1.70	1.80	1.92	2.05	4.95						
16.0	1.04	1.08	1.13	1.18	1.24	1.30	1.37	1.45	1.54	1.64	1.75	1.88	2.02	2.20	2.40							
17.0	1.05	1.10	1.15	1.21	1.28	1.36	1.44	1.54	1.65	1.78	1.93	2.11	2.33	2.60	2.93							
18.0	1.05	1.11	1.17	1.25	1.33	1.42	1.53	1.65	1.80	1.97	2.18	2.44	2.78	3.22	3.83							

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .75 — VALUES OF ECCENTRICITY RATIO $\delta e/t$																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
.010	4.48	4.07	3.91	3.76	3.60	3.46	3.32	2.98	2.68	2.42	2.18	1.79	1.41	0.88	0.60	0.22	0.13	0.08	1.00	108.9	79.6	3.50	1.91	0.30
.012	4.60	4.18	4.02	3.86	3.71	3.56	3.42	3.09	2.77	2.53	2.28	1.88	1.55	1.01	0.70	0.26	0.16	0.09	1.00	117.3	92.8	3.57	1.90	0.36
.014	4.73	4.29	4.13	3.97	3.81	3.66	3.52	3.18	2.88	2.63	2.39	1.98	1.68	1.12	0.79	0.30	0.18	0.10	1.00	125.7	105.5	3.64	1.90	0.41
.016	4.85	4.40	4.23	4.08	3.92	3.77	3.62	3.28	2.98	2.72	2.49	2.09	1.78	1.24	0.89	0.34	0.21	0.11	1.00	134.2	117.8	3.70	1.89	0.47
.018	4.98	4.51	4.34	4.18	4.02	3.86	3.72	3.37	3.07	2.81	2.59	2.18	1.85	1.36	0.98	0.38	0.23	0.13	1.03	142.6	129.8	3.77	1.89	0.52
.020	5.10	4.62	4.45	4.29	4.13	3.96	3.82	3.46	3.17	2.89	2.68	2.26	1.92	1.44	1.06	0.41	0.25	0.14	1.06	151.0	141.5	3.84	1.88	0.57
.022	5.23	4.73	4.55	4.39	4.23	4.06	3.92	3.56	3.26	2.97	2.76	2.34	2.02	1.55	1.16	0.45	0.28	0.16	1.09	159.5	153.0	3.91	1.88	0.63
.024	5.35	4.84	4.66	4.49	4.33	4.16	4.01	3.65	3.35	3.06	2.85	2.43	2.11	1.64	1.24	0.49	0.30	0.17	1.12	167.9	164.2	3.97	1.88	0.68
.026	5.47	4.95	4.77	4.60	4.43	4.27	4.11	3.75	3.44	3.15	2.92	2.52	2.19	1.72	1.32	0.53	0.32	0.18	1.15	176.4	175.2	4.04	1.87	0.73
.028	5.59	5.06	4.88	4.70	4.53	4.37	4.20	3.84	3.53	3.24	3.00	2.57	2.26	1.77	1.39	0.57	0.35	0.20	1.18	184.8	186.0	4.11	1.87	0.79
.030	5.70	5.17	4.98	4.80	4.64	4.47	4.30	3.94	3.61	3.33	3.07	2.65	2.33	1.81	1.47	0.60	0.37	0.21	1.20	193.2	196.7	4.18	1.86	0.84
.032	5.81	5.28	5.09	4.90	4.74	4.56	4.39	4.03	3.70	3.42	3.14	2.72	2.39	1.85	1.54	0.64	0.40	0.22	1.23	201.7	207.2	4.24	1.86	0.90
.034	5.91	5.39	5.20	5.00	4.84	4.66	4.49	4.12	3.78	3.50	3.21	2.79	2.46	1.92	1.61	0.68	0.42	0.24	1.26	210.1	217.6	4.31	1.86	0.95
.036	6.01	5.49	5.30	5.11	4.94	4.76	4.59	4.21	3.86	3.58	3.29	2.86	2.54	2.00	1.67	0.72	0.44	0.25	1.28	218.5	227.8	4.38	1.85	1.00
.038	6.12	5.60	5.41	5.21	5.04	4.86	4.68	4.30	3.94	3.67	3.38	2.94	2.59	2.07	1.73	0.75	0.47	0.26	1.30	227.0	238.0	4.45	1.85	1.06
.040	6.23	5.71	5.52	5.32	5.13	4.96	4.78	4.39	4.02	3.75	3.46	3.01	2.65	2.14	1.76	0.79	0.49	0.28	1.33	235.4	248.0	4.52	1.84	1.11
.042	6.36	5.82	5.62	5.42	5.23	5.06	4.88	4.48	4.10	3.83	3.54	3.08	2.72	2.20	1.79	0.83	0.51	0.29	1.35	243.9	257.9	4.58	1.84	1.16
.044	[illegible]	5.93	5.73	5.52	5.33	5.15	4.97	4.57	4.19	3.91	3.62	3.15	2.78	2.26	1.81	0.86	0.53	0.30	1.38	252.3	267.8	4.65	1.83	1.22
.046	[illegible]	6.03	5.83	5.63	5.43	5.25	5.07	4.66	4.28	3.99	3.70	3.21	2.85	2.32	1.84	0.90	0.56	0.32	1.40	260.7	277.5	4.72	1.83	1.27
.048	[illegible]	6.14	5.94	5.73	5.53	5.35	5.16	4.75	4.37	4.06	3.78	3.28	2.91	2.38	1.91	0.94	0.58	0.33	1.42	269.2	287.2	4.79	1.83	1.32
.050	6.84	6.25	6.04	5.83	5.63	5.45	5.26	4.84	4.45	4.14	3.86	3.35	2.97	2.43	1.98	0.98	0.61	0.34	1.44	277.6	296.8	4.85	1.82	1.38
.052	6.96	6.36	6.15	5.94	5.72	5.54	5.35	4.93	4.54	4.22	3.96	3.43	3.04	2.48	2.04	1.01	0.63	0.36	1.46	286.0	306.3	4.92	1.82	1.43
.054	7.08	6.47	6.25	6.04	5.82	5.64	5.45	5.01	4.62	4.29	4.02	3.51	3.10	2.53	2.10	1.05	0.65	0.37	1.49	294.5	315.8	4.99	1.81	1.48
.056	7.21	6.59	6.36	6.14	5.92	5.73	5.54	5.10	4.71	4.37	4.04	3.57	3.16	2.58	2.16	1.09	0.67	0.38	1.51	302.9	325.2	5.06	1.81	1.54
.058	7.33	6.70	6.46	6.25	6.02	5.83	5.64	5.19	4.79	4.44	4.12	3.63	3.22	2.62	2.22	1.13	0.70	0.40	1.53	311.4	334.5	5.13	1.80	1.59
060	7.45	6.81	6.57	6.35	6.12	5.93	5.73	5.27	4.88	4.52	4.19	3.69	3.29	2.67	2.27	1.16	0.72	0.41	1.55	319.8	343.8	5.19	1.80	1.64
.062	7.57	6.92	6.67	6.45	6.22	6.02	5.83	5.36	4.96	4.59	4.26	3.74	3.35	2.74	2.30	1.19	0.75	0.42	1.57	328.2	353.1	5.26	1.80	1.70
.064	7.69	7.04	6.78	6.55	6.32	6.12	5.92	5.44	5.05	4.67	4.34	3.80	3.41	2.77	2.35	1.23	0.77	0.44	1.59	336.7	362.3	5.33	1.79	1.75
.066	7.81	7.15	6.88	6.66	6.42	6.21	6.02	5.53	5.13	4.74	4.41	3.87	3.47	2.82	2.39	1.26	0.79	0.45	1.61	345.1	371.4	5.40	1.79	1.80
.068	7.94	7.26	6.98	6.76	6.52	6.31	6.11	5.61	5.22	4.81	4.48	3.94	3.53	2.88	2.44	1.30	0.81	0.46	1.63	353.5	380.5	5.46	1.78	1.86
.070	8.06	7.37	7.09	6.86	6.62	6.40	6.20	5.70	5.30	4.88	4.61	4.02	3.59	2.93	2.48	1.33	0.84	0.48	1.65	362.0	389.6	5.53	1.78	1.91
.072	8.18	7.48	7.19	6.96	6.72	6.50	6.30	5.78	5.38	4.96	4.68	4.09	3.65	2.98	2.52	1.36	0.86	0.49	1.67	370.4	398.6	5.60	1.77	1.97
.074	8.30	7.60	7.30	7.06	6.82	6.59	6.39	5.87	5.46	5.04	4.75	4.16	3.71	3.03	2.57	1.39	0.88	0.50	1.69	378.9	407.6	5.67	1.77	2.02
.076	8.42	7.71	7.40	7.17	6.92	6.68	6.48	5.95	5.55	5.12	4.82	4.23	3.77	3.08	2.61	1.42	0.91	0.51	1.70	387.3	416.6	5.74	1.77	2.07
.078	8.54	7.82	7.50	7.27	7.02	6.78	6.57	6.04	5.63	5.20	4.90	4.30	3.83	3.14	2.66	1.46	0.93	0.53	1.72	395.7	425.5	5.80	1.76	2.13
.080	8.66	7.93	7.61	7.37	7.12	6.87	6.67	6.13	5.71	5.28	4.97	4.32	3.88	3.19	2.70	1.49	0.95	0.54	1.74	404.2	434.4	5.87	1.76	2.18

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .9 — VALUES OF ECCENTRICITY RATIO $\delta e/t$																		Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00						
010	4.49	4.05	3.89	3.73	3.58	3.43	3.29	2.96	2.66	2.43	2.19	1.75	1.38	0.89	0.62	0.23	0.14	0.08	1.00	127.4	97.8	3.77	2.07	0.33
.012	4.62	4.17	4.01	3.85	3.69	3.55	3.41	3.07	2.78	2.54	2.32	1.89	1.54	1.02	0.73	0.27	0.16	0.09	1.02	139.6	114.6	3.84	2.07	0.39
.014	4.76	4.29	4.12	3.96	3.81	3.65	3.52	3.18	2.89	2.64	2.43	2.00	1.68	1.15	0.83	0.32	0.19	0.11	1.07	151.7	130.9	3.91	2.06	0.46
.016	4.89	4.40	4.23	4.08	3.92	3.76	3.62	3.28	3.00	2.73	2.54	2.12	1.79	1.27	0.92	0.36	0.22	0.12	1.11	163.9	146.8	3.97	2.06	0.52
.018	5.02	4.52	4.35	4.19	4.03	3.87	3.73	3.39	3.11	2.83	2.63	2.25	1.90	1.37	1.02	0.40	0.24	0.14	1.15	176.0	162.3	4.04	2.05	0.59
.020	5.14	4.63	4.46	4.30	4.14	3.98	3.83	3.50	3.20	2.94	2.72	2.32	1.96	1.48	1.11	0.45	0.27	0.15	1.19	188.2	177.5	4.11	2.05	0.65
.022	5.24	4.75	4.58	4.40	4.25	4.09	3.93	3.60	3.30	3.04	2.80	2.41	2.06	1.58	1.19	0.49	0.30	0.17	1.23	200.3	192.5	4.18	2.05	0.72
.024	5.34	4.86	4.69	4.51	4.36	4.20	4.04	3.70	3.39	3.14	2.87	2.50	2.19	1.68	1.28	0.53	0.32	0.18	1.26	212.5	207.3	4.24	2.04	0.78
026	5.44	4.97	4.80	4.62	4.46	4.30	4.15	3.80	3.48	3.23	2.98	2.58	2.29	1.76	1.36	0.57	0.35	0.20	1.30	224.6	221.8	4.31	2.04	0.85
028	5.56	5.09	4.91	4.73	4.57	4.41	4.25	3.90	3.57	3.32	3.07	2.66	2.35	1.83	1.45	0.62	0.38	0.21	1.33	236.8	236.2	4.38	2.03	0.91
.030	5.69	5.20	5.02	4.84	4.67	4.51	4.35	4.00	3.67	3.41	3.16	2.74	2.42	1.89	1.53	0.66	0.40	0.23	1.37	248.9	250.4	4.45	2.03	0.98
.032	5.81	5.31	5.13	4.95	4.77	4.62	4.46	4.09	3.76	3.49	3.25	2.82	2.50	1.95	1.61	0.69	0.43	0.24	1.40	261.1	264.4	4.52	2.02	1.04
.034	5.93	5.43	5.24	5.06	4.87	4.72	4.56	4.19	3.86	3.58	3.34	2.92	2.57	2.00	1.68	0.74	0.46	0.26	1.43	273.2	278.3	4.58	2.02	1.10
036	6.05	5.55	5.35	5.17	4.98	4.82	4.66	4.28	3.96	3.66	3.43	2.98	2.64	2.08	1.74	0.78	0.49	0.27	1.46	285.4	292.1	4.65	2.02	1.17
.038	6.18	5.67	5.46	5.28	5.09	4.92	4.76	4.37	4.05	3.74	3.51	3.04	2.71	2.19	1.79	0.82	0.51	0.29	1.49	297.5	305.8	4.72	2.01	1.23
040	6.30	5.79	5.57	5.38	5.19	5.02	4.86	4.46	4.14	3.81	3.59	3.11	2.78	2.28	1.84	0.86	0.53	0.30	1.52	309.7	319.3	4.79	2.01	1.30
.042	6.42	5.90	5.67	5.49	5.30	5.12	4.96	4.55	4.23	3.90	3.67	3.20	2.85	2.32	1.88	0.90	0.56	0.32	1.55	321.8	332.7	4.85	2.00	1.36
.044	6.54	6.02	5.78	5.59	5.40	5.22	5.06	4.64	4.32	3.99	3.75	3.28	2.92	2.38	1.92	0.93	0.59	0.33	1.58	334.0	346.1	4.92	2.00	1.43
.046	6.66	6.14	5.89	5.70	5.51	5.31	5.15	4.74	4.41	4.08	3.82	3.37	2.98	2.44	1.96	0.97	0.61	0.35	1.61	346.1	359.3	4.99	1.99	1.49
.048	6.79	6.26	6.00	5.81	5.61	5.42	5.25	4.84	4.50	4.17	3.90	3.40	3.05	2.50	1.99	1.01	0.64	0.36	1.64	358.3	372.5	5.06	1.99	1.56
050	6.91	6.37	6.12	5.91	5.72	5.52	5.35	4.93	4.58	4.26	3.97	3.47	3.11	2.56	2.09	1.05	0.66	0.38	1.67	370.4	385.6	5.13	1.99	[illegible]
.052	7.03	6.49	6.23	6.02	5.82	5.62	5.44	5.03	4.67	4.34	4.04	3.55	3.19	2.62	2.18	1.09	0.69	0.39	1.69	382.6	398.7	5.19	1.98	1.69
.054	7.16	6.60	6.34	6.12	5.92	5.73	5.54	5.12	4.75	4.43	4.11	3.62	3.25	2.66	2.27	1.13	0.71	0.41	1.72	394.7	411.6	5.26	1.98	1.75
.056	7.28	6.72	6.46	6.22	6.03	5.83	5.63	5.22	4.84	4.51	4.19	3.69	3.30	2.72	2.30	1.17	0.74	0.42	1.75	406.9	424.5	5.33	1.97	1.82
.058	7.40	6.83	6.57	6.33	6.13	5.93	5.73	5.31	4.92	4.60	4.26	3.76	3.36	2.77	2.35	1.20	0.76	0.44	1.77	419.0	437.4	5.40	1.97	1.88
.060	7.52	6.94	6.68	6.43	6.23	6.03	5.82	5.41	5.01	4.68	4.34	3.84	3.44	2.83	2.40	1.24	0.79	0.45	1.80	431.2	450.2	5.46	1.97	1.94
.062	7.64	7.04	6.80	6.53	6.33	6.13	5.92	5.50	5.09	4.77	4.43	3.91	3.51	2.88	2.45	1.28	0.82	0.47	1.82	443.3	462.9	5.53	1.96	2.01
.064	7.77	7.14	6.91	6.64	6.44	6.23	6.02	5.59	5.17	4.85	4.51	3.98	3.55	2.94	2.51	1.31	0.84	0.48	1.85	455.5	475.6	5.60	1.96	2.07
066	7.89	7.24	7.02	6.75	6.54	6.33	6.12	5.68	5.25	4.93	4.59	4.05	3.61	2.99	2.56	1.35	0.87	0.49	1.87	467.6	488.2	5.67	1.95	2.14
.068	8.01	7.34	7.13	6.86	6.64	6.43	6.22	5.77	5.33	5.01	4.67	4.12	3.68	3.05	2.59	1.38	0.89	0.51	1.90	479.8	500.8	5.74	1.95	2.20
.070	8.14	7.44	7.24	6.97	6.74	6.53	6.32	5.87	5.42	5.09	4.76	4.19	3.74	3.10	2.64	1.42	0.91	0.52	1.92	491.9	513.4	5.80	1.94	2.27
.072	8.26	7.54	7.35	7.08	6.84	6.63	6.42	5.96	5.51	5.17	4.84	4.26	3.81	3.16	2.68	1.46	0.94	0.54	1.94	504.1	525.9	5.87	1.94	2.33
.074	8.38	7.65	7.47	7.18	6.94	6.73	6.52	6.05	5.59	5.25	4.92	4.33	3.87	3.21	2.73	1.49	0.96	0.55	1.97	516.2	538.4	5.94	1.94	2.40
076	8.50	7.76	7.58	7.29	7.04	6.83	6.61	6.14	5.68	5.33	5.00	4.40	3.94	3.27	2.78	1.53	0.99	0.57	1.99	528.4	550.8	6.01	1.93	2.46
.078	8.63	7.88	7.69	7.40	7.14	6.93	6.71	6.23	5.77	5.41	5.08	4.46	4.00	3.32	2.83	1.56	1.01	0.58	2.01	540.5	563.2	6.07	1.93	2.53
.080	8.75	7.99	7.80	7.51	7.24	7.03	6.81	6.32	5.86	5.49	5.16	4.53	4.06	3.37	2.88	1.60	1.04	0.60	2.04	552.7	575.6	6.14	1.92	2.59

Table 6.6A.6 Values of ultimate axial stress, P_u/A_g, for rectangular column with symmetric reinforcing steel, f'_c = 5 ksi, f_{dy} = 72 ksi, γ = 0.45, 0.60, 0.75, 0.90



p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .45 — VALUES OF ECCENTRICITY RATIO $6e/t$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. t Ratio t_e/t	EI_b/bt^3	EI_t/bt^3	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	M_u/bt^2
.010	5.49	5.05	4.87	4.70	4.53	4.35	4.18	3.75	3.34	2.96	2.62	2.06	1.63	1.02	0.71	0.27	0.16	0.09	1.00	98.5	55.3	3.40	1.70	0.31
.012	5.60	5.15	4.97	4.79	4.61	4.43	4.26	3.83	3.41	3.03	2.68	2.12	1.70	1.13	0.79	0.30	0.19	0.11	1.00	101.6	63.8	3.47	1.67	0.35
014	5.71	5.25	5.07	4.88	4.70	4.52	4.34	3.90	3.47	3.09	2.73	2.20	1.79	1.23	0.85	0.33	0.21	0.12	1.00	104.6	71.8	3.53	1.64	0.39
.016	5.83	5.36	5.17	4.98	4.79	4.60	4.42	3.98	3.54	3.16	2.79	2.28	1.87	1.30	0.92	0.36	0.23	0.13	1.00	107.6	79.5	3.60	1.60	0.43
.018	5.94	5.46	5.26	5.07	4.88	4.69	4.50	4.05	3.61	3.22	2.84	2.30	1.93	1.36	1.00	0.39	0.24	0.14	1.00	110.7	86.8	3.66	1.57	0.47
.020	6.05	5.56	5.36	5.16	4.97	4.77	4.59	4.12	3.68	3.29	2.90	2.36	1.98	1.42	1.06	0.42	0.26	0.15	1.00	113.7	93.9	3.73	1.53	0.50
.022	6.16	5.66	5.46	5.26	5.06	4.86	4.67	4.20	3.74	3.35	2.97	2.42	2.02	1.47	1.12	0.45	0.28	0.16	1.00	116.7	100.6	3.79	1.50	0.54
.024	6.28	5.76	5.55	5.35	5.15	4.94	4.75	4.27	3.81	3.41	3.03	2.47	2.06	1.53	1.18	0.48	0.30	0.17	1.00	119.8	107.2	3.86	1.46	0.57
.026	6.39	5.86	5.65	5.44	5.24	5.03	4.83	4.35	3.88	3.48	3.09	2.53	2.13	1.60	1.23	0.51	0.32	0.18	1.00	122.8	113.5	3.92	1.43	0.61
.028	6.50	5.96	5.75	5.53	5.32	5.11	4.91	4.42	3.95	3.54	3.15	2.58	2.16	1.63	1.27	0.54	0.33	0.19	1.00	125.9	119.7	3.98	1.39	0.64
.030	6.62	6.07	5.85	5.63	5.41	5.20	4.99	4.49	4.01	3.60	3.22	2.64	2.21	1.67	1.31	0.56	0.35	0.20	1.00	128.9	125.7	4.05	1.36	0.68
.032	6.73	6.17	5.94	5.72	5.50	5.28	5.07	4.57	4.08	3.67	3.28	2.69	2.26	1.72	1.36	0.59	0.37	0.21	1.00	131.9	131.5	4.11	1.32	0.71
.034	6.84	6.27	6.04	5.81	5.59	5.36	5.16	4.64	4.15	3.73	3.34	2.74	2.31	1.76	1.40	0.62	0.39	0.22	1.00	135.0	137.2	4.18	1.29	0.75
.036	6.95	6.37	6.14	5.91	5.68	5.45	5.24	4.72	4.22	3.79	3.40	2.79	2.35	1.80	1.43	0.64	0.40	0.23	1.00	138.0	142.8	4.24	1.25	0.78
.038	7.07	6.47	6.23	6.00	5.77	5.53	5.32	4.79	4.28	3.85	3.46	2.85	2.40	1.83	1.47	0.67	0.42	0.24	1.00	141.0	148.2	4.31	1.22	0.81
.040	7.18	6.57	6.33	6.09	5.86	5.62	5.40	4.87	4.35	3.92	3.52	2.90	2.45	1.86	1.51	0.69	0.44	0.25	1.00	144.1	153.6	4.37	1.18	0.85
.042	7.29	6.67	6.43	6.18	5.95	5.70	5.48	4.94	4.42	3.98	3.59	2.95	2.50	1.90	1.53	0.72	0.45	0.26	1.00	147.1	158.8	4.44	1.15	0.88
.044	7.41	6.78	6.52	6.28	6.03	5.78	5.56	5.01	4.49	4.04	3.65	3.00	2.52	1.95	1.57	0.74	0.47	0.27	1.00	150.2	163.9	4.50	1.11	0.91
.046	7.52	6.88	6.62	6.37	6.12	5.87	5.65	5.09	4.56	4.10	3.64	3.04	2.56	1.97	1.59	0.77	0.48	0.28	1.00	153.2	169.0	4.57	1.08	0.95
.048	7.63	6.98	6.72	6.46	6.21	5.95	5.73	5.16	4.62	4.16	3.69	3.09	2.61	2.00	1.63	0.79	0.50	0.29	1.00	156.2	173.9	4.63	1.04	0.98
.050	7.75	7.08	6.81	6.55	6.30	6.04	5.81	5.24	4.69	4.22	3.75	3.14	2.65	2.05	1.66	0.82	0.52	0.30	1.00	159.3	178.8	4.69	1.01	1.01
.052	7.86	7.18	6.91	6.65	6.39	6.12	5.89	5.31	4.76	4.28	3.80	3.19	2.70	2.06	1.68	0.84	0.53	0.31	1.00	162.3	183.6	4.76	0.97	1.04
054	7.97	7.28	7.01	6.74	6.48	6.21	5.97	5.39	4.83	4.35	3.86	3.24	2.74	2.10	1.72	0.87	0.55	0.32	1.00	165.3	188.3	4.82	0.94	1.08
.056	8.08	7.39	7.10	6.83	6.57	6.29	6.05	5.46	4.89	4.41	3.92	3.28	2.79	2.14	1.74	0.88	0.57	0.33	1.01	168.4	192.9	4.89	0.90	1.11
.058	8.20	7.49	7.20	6.93	6.65	6.38	6.14	5.54	4.96	4.47	3.97	3.33	2.83	2.17	1.77	0.91	0.58	0.33	1.01	171.4	197.5	4.95	0.87	1.14
.060	8.31	7.59	7.30	7.02	6.74	6.46	6.22	5.61	5.03	4.53	4.03	3.37	2.87	2.21	1.80	0.92	0.60	0.34	1.02	174.5	202.1	5.02	0.83	1.17
.062	8.42	7.69	7.39	7.11	6.83	6.55	6.30	5.68	5.10	4.59	4.08	3.42	2.92	2.25	1.83	0.94	0.61	0.35	1.03	177.5	206.5	5.08	0.80	1.20
.064	8.54	7.79	7.49	7.20	6.92	6.63	6.38	5.76	5.17	4.65	4.14	3.47	2.96	2.27	1.86	0.96	0.63	0.36	1.04	180.5	210.9	5.15	0.77	1.24
.066	8.65	7.89	7.59	7.30	7.01	6.72	6.46	5.83	5.23	4.71	4.20	3.51	3.01	2.30	1.89	0.97	0.65	0.37	1.05	183.6	215.3	5.21	0.73	1.27
.068	8.76	7.99	7.68	7.39	7.10	6.80	6.54	5.91	5.30	4.77	4.25	3.55	3.05	2.34	1.91	0.99	0.66	0.38	1.06	186.6	219.6	5.27	0.70	1.30
.070	8.88	8.10	7.78	7.48	7.18	6.89	6.63	5.98	5.37	4.83	4.31	3.60	3.07	2.37	1.94	1.00	0.67	0.39	1.07	189.6	223.9	5.34	0.66	1.33
.072	8.99	8.20	7.88	7.57	7.27	6.97	6.71	6.06	5.44	4.89	4.36	3.67	3.11	2.41	1.95	1.02	0.69	0.40	1.08	192.7	228.1	5.40	0.63	1.36
074	9.10	8.30	7.97	7.67	7.36	7.06	6.79	6.13	5.50	4.95	4.42	3.71	3.15	2.44	1.98	1.03	0.70	0.41	1.08	195.7	232.3	5.47	0.59	1.40
.076	9.22	8.40	8.07	7.76	7.45	7.14	6.87	6.21	5.57	5.01	4.48	3.75	3.19	2.48	2.01	1.05	0.71	0.42	1.09	198.8	236.5	5.53	0.56	1.43
.078	9.33	8.50	8.17	7.85	7.54	7.23	6.95	6.28	5.64	5.08	4.53	3.79	3.24	2.51	2.04	1.06	0.72	0.43	1.10	201.8	240.6	5.60	0.52	1.46
.080	9.44	8.60	8.26	7.94	7.63	7.31	7.04	6.36	5.71	5.14	4.59	.3.83	3.28	2.55	2.07	1.08	0.73	0.44	1.11	204.8	244.6	5.66	0.49	1.49

p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6 — VALUES OF ECCENTRICITY RATIO $6e/t$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. t Ratio t_e/t	EI_b/bt^3	EI_t/bt^3	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	M_u/bt^2
.010	5.46	4.98	4.80	4.61	4.43	4.25	4.07	3.64	3.24	2.90	2.60	2.07	1.59	0.96	0.65	0.24	0.15	0.09	1.00	110.3	67.3	3.73	2.02	0.30
.012	5.57	5.09	4.90	4.71	4.52	4.34	4.16	3.73	3.33	3.00	2.68	2.20	1.73	1.07	0.74	0.28	0.17	0.10	1.00	115.7	78.1	3.80	2.01	0.35
.014	5.69	5.19	5.00	4.81	4.62	4.43	4.25	3.81	3.42	3.08	2.76	2.27	1.84	1.18	0.82	0.31	0.19	0.11	1.00	121.1	88.5	3.87	2.00	0.40
.016	5.80	5.30	5.10	4.90	4.71	4.52	4.34	3.90	3.51	3.17	2.85	2.36	1.94	1.29	0.91	0.35	0.21	0.12	1.00	126.5	98.3	3.93	1.99	0.44
.018	5.91	5.40	5.20	5.00	4.81	4.61	4.43	3.98	3.59	3.25	2.94	2.45	2.04	1.39	0.98	0.38	0.23	0.13	1.00	131.9	108.1	4.00	1.97	0.49
.020	6.02	5.51	5.30	5.10	4.90	4.71	4.52	4.06	3.68	3.33	3.03	2.53	2.16	1.48	1.07	0.42	0.26	0.14	1.00	137.3	117.4	4.07	1.96	0.53
.022	6.14	5.61	5.40	5.20	5.00	4.80	4.61	4.15	3.76	3.41	3.11	2.61	2.21	1.58	1.14	0.45	0.28	0.16	1.00	142.7	126.5	4.13	1.95	0.58
.024	6.25	5.72	5.50	5.29	5.09	4.89	4.70	4.23	3.84	3.48	3.19	2.68	2.28	1.67	1.22	0.48	0.30	0.17	1.00	148.1	135.3	4.20	1.94	0.62
.026	6.37	5.82	5.61	5.39	5.19	4.98	4.79	4.32	3.92	3.56	3.27	2.75	2.36	1.74	1.29	0.52	0.32	0.18	1.00	153.5	143.9	4.27	1.93	0.67
.028	6.48	5.92	5.71	5.49	5.28	5.07	4.87	4.40	4.01	3.63	3.35	2.82	2.43	1.81	1.37	0.55	0.34	0.19	1.00	158.9	152.4	4.33	1.92	0.71
.030	6.59	6.03	5.81	5.58	5.38	5.17	4.96	4.49	4.09	3.70	3.42	2.91	2.50	1.86	1.43	0.58	0.36	0.20	1.00	164.3	160.6	4.40	1.91	0.75
.032	6.71	6.13	5.91	5.68	5.47	5.26	5.05	4.57	4.17	3.77	3.50	2.97	2.57	1.93	1.51	0.61	0.38	0.22	1.01	169.7	168.7	4.47	1.90	0.80
.034	6.82	6.24	6.01	5.78	5.57	5.35	5.14	4.66	4.25	3.84	3.57	3.02	2.65	2.02	1.58	0.65	0.40	0.23	1.03	175.1	176.7	4.53	1.89	0.84
.036	6.93	6.34	6.11	5.87	5.66	5.44	5.22	4.74	4.33	3.92	3.64	3.07	2.68	2.08	1.64	0.68	0.42	0.24	1.04	180.5	184.5	4.60	1.88	0.88
.038	7.05	6.45	6.21	5.97	5.75	5.53	5.31	4.83	4.40	4.00	3.71	3.14	2.75	2.14	1.70	0.71	0.44	0.25	1.06	185.9	192.2	4.67	1.87	0.93
.040	7.16	6.55	6.31	6.07	5.85	5.62	5.40	4.91	4.48	4.08	3.78	3.21	2.81	2.20	1.74	0.74	0.46	0.26	1.07	191.3	199.8	4.73	1.85	0.97
.042	7.28	6.65	6.41	6.17	5.94	5.72	5.49	4.99	4.56	4.15	3.85	3.29	2.87	2.25	1.78	0.77	0.48	0.27	1.09	196.7	207.2	4.80	1.84	1.01
.044	7.39	6.76	6.51	6.26	6.04	5.81	5.57	5.08	4.64	4.23	3.92	3.36	2.92	2.31	1.81	0.80	0.50	0.29	1.10	202.1	214.6	4.87	1.83	1.06
.046	7.51	6.86	6.61	6.36	6.13	5.90	5.66	5.16	4.72	4.31	3.99	3.43	2.98	2.35	1.87	0.84	0.52	0.30	1.12	207.5	221.9	4.93	1.82	1.10
.048	7.63	6.97	6.72	6.46	6.22	5.99	5.75	5.24	4.79	4.38	4.05	3.45	3.04	2.40	1.95	0.87	0.54	0.31	1.13	212.9	229.0	5.00	1.81	1.14
.050	7.75	7.07	6.82	6.56	6.32	6.08	5.84	5.33	4.87	4.46	4.12	3.52	3.12	2.45	2.02	0.90	0.56	0.32	1.14	218.3	236.1	5.07	1.80	1.19
.052	7.87	7.17	6.92	6.65	6.41	6.17	5.93	5.41	4.95	4.54	4.18	3.58	3.17	2.51	2.05	0.93	0.58	0.33	1.16	223.7	243.2	5.13	1.79	1.23
.054	7.99	7.28	7.02	6.75	6.51	6.26	6.02	5.49	5.02	4.61	4.25	3.64	3.22	2.56	2.10	0.96	0.60	0.34	1.17	229.1	250.1	5.20	1.78	1.27
.056	8.11	7.38	7.12	6.85	6.60	6.36	6.10	5.57	5.10	4.69	4.31	3.71	3.28	2.61	2.15	0.99	0.62	0.35	1.19	234.5	257.0	5.27	1.77	1.31
.058	8.24	7.48	7.22	6.95	6.70	6.45	6.19	5.66	5.17	4.77	4.38	3.77	3.33	2.67	2.19	1.02	0.64	0.37	1.20	239.9	263.8	5.33	1.76	1.36
.060	8.36	7.59	7.32	7.04	6.79	6.54	6.28	5.74	5.25	4.84	4.44	3.83	3.40	2.72	2.22	1.06	0.66	0.38	1.21	245.3	270.5	5.40	1.75	1.40
.062	8.48	7.69	7.42	7.14	6.88	6.63	6.37	5.82	5.32	4.91	4.50	3.89	3.44	2.75	2.27	1.08	0.68	0.39	1.23	250.7	277.2	5.47	1.73	1.44
.064	8.60	7.80	7.52	7.24	6.97	6.72	6.46	5.91	5.40	4.98	4.57	3.96	3.48	2.80	2.31	1.11	0.71	0.40	1.24	256.1	283.8	5.53	1.72	1.48
.066	8.72	7.90	7.62	7.34	7.07	6.81	6.55	5.99	5.47	5.06	4.63	4.02	3.53	2.85	2.35	1.14	0.72	0.41	1.25	261.5	290.4	5.60	1.71	1.53
.068	8.84	8.01	7.72	7.43	7.16	6.90	6.64	6.07	5.55	5.13	4.69	4.08	3.59	2.90	2.40	1.18	0.74	0.42	1.27	266.9	297.0	5.67	1.70	1.57
.070	8.96	8.11	7.83	7.53	7.25	6.99	6.72	6.15	5.62	5.20	4.76	4.14	3.66	2.96	2.44	1.21	0.76	0.43	1.28	272.3	303.4	5.73	1.69	1.61
.072	9.08	8.22	7.93	7.63	7.35	7.08	6.81	6.23	5.70	5.28	4.83	4.20	3.72	3.01	2.49	1.24	0.78	0.44	1.29	277.7	309.9	5.80	1.68	1.65
.074	9.20	8.32	8.03	7.73	7.44	7.18	6.90	6.32	5.77	5.35	4.90	4.26	3.79	3.05	2.51	1.27	0.80	0.46	1.30	283.1	316.3	5.87	1.67	1.70
.076	9.32	8.43	8.13	7.82	7.53	7.27	6.99	6.40	5.85	5.42	4.97	4.32	3.80	3.10	2.56	1.30	0.82	0.47	1.32	288.5	322.6	5.93	1.66	1.74
.078	9.44	8.53	8.23	7.92	7.63	7.36	7.08	6.48	5.92	5.49	5.04	4.39	3.85	3.15	2.60	1.33	0.84	0.48	1.33	293.9	328.9	6.00	1.65	1.78
.080	9.56	8.64	8.33	8.02	7.72	7.45	7.17	6.56	5.99	5.57	5.11	4.45	3.91	3.19	2.64	1.36	0.86	0.49	1.34	299.3	335.2	6.07	1.64	1.83

L/t_e	VALUES OF MOMENT MULTIPLIERS δ — VALUES OF ULTIMATE STRESS P_u/A_g IN KSI: 0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02
3.0	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.05	1.05
4.0	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.05	1.05	1.06	1.07	1.08	1.08	1.09
5.0	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.08	1.09	1.10	1.11	1.13	1.14	1.15
6.0	1.00	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.07	1.11	1.13	1.15	1.17	1.19	1.21	1.23
7.0	1.01	1.01	1.02	1.02	1.03	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.08	1.09	1.10	1.16	1.19	1.22	1.25	1.28	1.31	1.35
8.0	1.01	1.02	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.08	1.09	1.10	1.11	1.12	1.13	1.22	1.26	1.30	1.35	1.40	1.45	1.51
9.0	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.11	1.12	1.13	1.15	1.16	1.17	1.30	1.36	1.42	1.49	1.57	1.65	1.74
10.0	1.01	1.02	1.04	1.05	1.06	1.08	1.09	1.11	1.12	1.14	1.15	1.17	1.19	1.21	1.22	1.40	1.48	1.57	1.68	1.80	1.95	2.11
11.0	1.01	1.03	1.05	1.06	1.08	1.10	1.11	1.13	1.15	1.17	1.19	1.21	1.24	1.26	1.28	1.52	1.65	1.79	1.96	2.17	2.43	2.76
12.0	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.19	1.21	1.24	1.27	1.29	1.32	1.36	1.69	1.88	2.11	2.40	2.79	3.34	4.14
13.0	1.02	1.04	1.07	1.09	1.11	1.14	1.17	1.20	1.23	1.26	1.29	1.33	1.36	1.40	1.45	1.92	2.21	2.61	3.17	4.06	5.62	9.13
14.0	1.02	1.05	1.08	1.11	1.14	1.17	1.20	1.24	1.27	1.31	1.36	1.40	1.45	1.50	1.56	2.25	2.74	3.51	4.86	7.92		
15.0	1.03	1.06	1.09	1.12	1.16	1.20	1.24	1.28	1.33	1.38	1.43	1.49	1.55	1.62	1.70	2.76	3.70	5.58				
16.0	1.03	1.07	1.10	1.14	1.18	1.23	1.28	1.33	1.39	1.45	1.52	1.60	1.68	1.77	1.88	3.65	5.88					
17.0	1.04	1.08	1.12	1.16	1.21	1.27	1.33	1.39	1.46	1.54	1.63	1.73	1.84	1.97	2.11	5.55						
18.0	1.04	1.09	1.13	1.19	1.25	1.31	1.38	1.46	1.55	1.65	1.76	1.90	2.05	2.23	2.44							

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .75$ — VALUES OF ECCENTRICITY RATIO $\delta e/t$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
.010	5.43	4.94	4.74	4.55	4.36	4.17	3.99	3.56	3.17	2.85	2.54	2.04	1.57	0.94	0.62	0.23	0.14	0.08	1.00	125.5	82.3	4.05	2.24	0.31
.012	5.55	5.05	4.85	4.65	4.46	4.27	4.09	3.66	3.28	2.96	2.65	2.16	1.71	1.08	0.73	0.27	0.16	0.09	1.00	134.0	96.1	4.12	2.24	0.36
.014	5.67	5.15	4.95	4.76	4.57	4.37	4.19	3.76	3.38	3.06	2.77	2.26	1.87	1.19	0.83	0.31	0.19	0.10	1.00	142.4	109.4	4.19	2.23	0.42
.016	5.78	5.26	5.06	4.86	4.67	4.47	4.29	3.85	3.49	3.16	2.88	2.37	2.00	1.31	0.92	0.35	0.21	0.12	1.00	150.8	122.3	4.25	2.23	0.47
.018	5.90	5.37	5.17	4.96	4.77	4.58	4.39	3.95	3.58	3.25	2.98	2.48	2.10	1.44	1.02	0.38	0.24	0.13	1.00	159.3	134.9	4.32	2.22	0.53
.020	6.02	5.48	5.27	5.06	4.87	4.68	4.49	4.05	3.68	3.33	3.07	2.57	2.17	1.55	1.11	0.42	0.26	0.15	1.00	167.7	147.1	4.39	2.21	0.58
.022	6.13	5.59	5.38	5.17	4.97	4.78	4.58	4.15	3.77	3.41	3.16	2.65	2.24	1.64	1.19	0.46	0.28	0.16	1.03	176.1	159.1	4.45	2.21	0.64
.024	6.25	5.70	5.49	5.27	5.07	4.88	4.68	4.24	3.86	3.51	3.24	2.73	2.34	1.76	1.29	0.50	0.31	0.17	1.05	184.6	170.8	4.52	2.20	0.69
.026	6.36	5.80	5.59	5.38	5.17	4.98	4.77	4.34	3.95	3.60	3.32	2.83	2.43	1.86	1.37	0.54	0.33	0.19	1.08	193.0	182.4	4.59	2.20	0.74
.028	6.49	5.91	5.70	5.48	5.27	5.07	4.87	4.43	4.04	3.69	3.40	2.92	2.52	1.95	1.47	0.58	0.35	0.20	1.10	201.5	193.7	4.65	2.19	0.80
.030	6.62	6.02	5.80	5.58	5.37	5.17	4.97	4.53	4.12	3.78	3.47	2.97	2.59	2.03	1.55	0.62	0.38	0.21	1.12	209.9	204.8	4.72	2.19	0.85
.032	6.75	6.13	5.91	5.69	5.47	5.27	5.07	4.62	4.21	3.87	3.55	3.04	2.67	2.08	1.61	0.65	0.40	0.23	1.14	218.2	215.8	4.79	2.18	0.91
.034	6.88	6.24	6.01	5.79	5.57	5.37	5.16	4.71	4.29	3.95	3.62	3.12	2.73	2.12	1.70	0.69	0.43	0.24	1.17	226.6	226.6	4.85	2.18	0.96
.036	7.01	6.34	6.12	5.89	5.67	5.47	5.26	4.80	4.37	4.04	3.69	3.19	2.80	2.16	1.78	0.73	0.45	0.25	1.19	235.2	237.3	4.92	2.17	1.01
.038	7.14	6.45	6.22	5.99	5.77	5.56	5.36	4.89	4.45	4.12	3.78	3.26	2.86	2.22	1.85	0.77	0.47	0.27	1.21	243.6	247.9	4.99	2.17	1.07
.040	7.27	6.56	6.33	6.10	5.86	5.66	5.45	4.98	4.53	4.21	3.86	3.34	2.95	2.30	1.92	0.80	0.50	0.28	1.23	252.1	258.3	5.05	2.16	1.12
.042	7.40	6.67	6.43	6.20	5.96	5.76	5.55	5.07	4.62	4.29	3.95	3.41	2.99	2.37	1.98	0.84	0.52	0.29	1.25	260.5	268.6	5.12	2.16	1.17
.044	7.52	6.78	6.54	6.30	6.06	5.85	5.64	5.16	4.71	4.37	4.03	3.48	3.06	2.44	2.03	0.88	0.54	0.31	1.27	269.0	278.8	5.19	2.15	1.23
.046	7.63	6.89	6.64	6.40	6.16	5.95	5.74	5.24	4.80	4.45	4.11	3.55	3.12	2.51	2.06	0.92	0.57	0.32	1.29	277.4	288.9	5.25	2.15	1.28
.048	7.74	6.99	6.74	6.51	6.26	6.04	5.83	5.33	4.88	4.52	4.19	3.62	3.19	2.58	2.08	0.95	0.59	0.33	1.31	285.8	299.0	5.32	2.14	1.33
.050	7.85	7.10	6.85	6.61	6.36	6.14	5.92	5.42	4.97	4.60	4.27	3.69	3.25	2.64	2.11	0.99	0.61	0.35	1.33	294.3	308.9	5.39	2.13	1.39
.052	7.95	7.21	6.95	6.71	6.46	6.23	6.02	5.50	5.06	4.68	4.35	3.75	3.32	2.69	2.13	1.03	0.64	0.36	1.35	302.7	318.8	5.45	2.13	1.44
.054	8.06	7.32	7.05	6.81	6.56	6.33	6.11	5.59	5.14	4.75	4.43	3.82	3.38	2.75	2.20	1.06	0.66	0.37	1.37	311.1	328.6	5.52	2.12	1.50
.056	8.17	7.43	7.16	6.91	6.66	6.42	6.21	5.68	5.23	4.83	4.50	3.89	3.44	2.80	2.27	1.10	0.68	0.39	1.38	319.6	338.3	5.59	2.12	1.55
.058	8.28	7.53	7.26	7.01	6.76	6.52	6.30	5.76	5.31	4.90	4.58	3.99	3.51	2.86	2.33	1.14	0.70	0.40	1.40	328.0	347.9	5.65	2.11	1.60
.060	8.39	7.64	7.36	7.11	6.86	6.61	6.39	5.85	5.40	4.98	4.65	4.05	3.57	2.91	2.40	1.17	0.73	0.41	1.42	336.5	357.5	5.72	2.11	1.66
.062	8.50	7.75	7.47	7.22	6.96	6.70	6.48	5.93	5.48	5.05	4.73	4.11	3.63	2.95	2.46	1.21	0.75	0.43	1.44	344.9	367.0	5.79	2.10	1.71
.064	8.61	7.86	7.57	7.32	7.06	6.80	6.58	6.02	5.56	5.13	4.80	4.16	3.69	3.00	2.52	1.25	0.77	0.44	1.46	353.3	376.5	5.85	2.10	1.76
.066	8.72	7.97	7.68	7.42	7.15	6.89	6.67	6.10	5.65	5.20	4.88	4.22	3.76	3.04	2.57	1.29	0.80	0.45	1.47	361.8	385.9	5.92	2.09	1.82
.068	8.83	8.07	7.78	7.52	7.25	6.99	6.76	6.18	5.73	5.27	4.95	4.28	3.82	3.10	2.63	1.32	0.82	0.47	1.49	370.2	395.2	5.99	2.09	1.87
.070	8.94	8.18	7.89	7.62	7.35	7.08	6.85	6.27	5.81	5.34	5.02	4.33	3.88	3.17	2.65	1.36	0.85	0.48	1.51	378.6	404.5	6.05	2.08	1.92
.072	9.06	8.29	7.99	7.72	7.45	7.17	6.95	6.35	5.89	5.42	5.10	4.41	3.94	3.19	2.70	1.39	0.87	0.49	1.52	387.1	413.8	6.12	2.08	1.98
.074	9.18	8.40	8.10	7.82	7.55	7.27	7.04	6.44	5.98	5.49	5.17	4.48	4.00	3.24	2.74	1.43	0.89	0.51	1.54	395.5	423.0	6.19	2.07	2.03
.076	9.30	8.50	8.20	7.92	7.65	7.37	7.13	6.53	6.06	5.57	5.24	4.55	4.06	3.30	2.79	1.46	0.91	0.52	1.56	404.0	432.2	6.25	2.07	2.08
.078	9.42	8.61	8.31	8.02	7.75	7.46	7.22	6.62	6.14	5.65	5.31	4.63	4.12	3.35	2.83	1.49	0.94	0.53	1.57	412.4	441.3	6.32	2.06	2.14
.080	9.54	8.72	8.41	8.12	7.84	7.56	7.31	6.71	6.22	5.73	5.38	4.70	4.18	3.40	2.87	1.53	0.96	0.55	1.59	420.8	450.4	6.39	2.06	2.19

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .9$ — VALUES OF ECCENTRICITY RATIO $\delta e/t$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.t Ratio t_e/t	$\frac{EI_b}{bt^3}$	$\frac{EI_t}{bt^3}$	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$	$\frac{M_u}{bt^2}$
.010	5.42	4.90	4.70	4.50	4.31	4.11	3.94	3.52	3.13	2.83	2.52	1.98	1.52	0.93	0.64	0.23	0.14	0.08	1.00	144.1	100.5	4.37	2.44	0.33
.012	5.54	5.02	4.81	4.61	4.42	4.23	4.05	3.63	3.26	2.95	2.67	2.14	1.67	1.07	0.75	0.27	0.16	0.09	1.00	156.2	117.8	4.44	2.43	0.40
.014	5.66	5.13	4.93	4.72	4.53	4.34	4.16	3.73	3.38	3.06	2.80	2.27	1.84	1.21	0.86	0.32	0.19	0.11	1.01	168.4	134.7	4.50	2.42	0.46
.016	5.78	5.25	5.04	4.83	4.65	4.45	4.27	3.85	3.49	3.16	2.91	2.38	1.98	1.34	0.96	0.36	0.22	0.12	1.04	180.5	151.2	4.57	2.42	0.52
.018	5.90	5.36	5.16	4.95	4.75	4.56	4.37	3.96	3.60	3.26	3.01	2.51	2.11	1.47	1.06	0.41	0.24	0.14	1.08	192.7	167.3	4.64	2.41	0.59
.020	6.04	5.47	5.27	5.06	4.86	4.67	4.48	4.06	3.70	3.37	3.10	2.64	2.21	1.58	1.15	0.45	0.27	0.15	1.11	204.8	183.0	4.70	2.41	0.65
.022	6.18	5.59	5.38	5.17	4.97	4.78	4.59	4.17	3.79	3.47	3.19	2.75	2.30	1.67	1.24	0.49	0.30	0.17	1.14	217.0	198.5	4.77	2.40	0.72
.024	6.32	5.70	5.49	5.28	5.07	4.89	4.70	4.27	3.89	3.57	3.27	2.81	2.38	1.79	1.33	0.54	0.33	0.18	1.17	229.1	213.8	4.84	2.40	0.78
.026	6.47	5.82	5.60	5.39	5.18	4.99	4.80	4.37	3.97	3.67	3.36	2.89	2.51	1.90	1.42	0.58	0.35	0.20	1.20	241.3	228.8	4.90	2.39	0.85
.028	6.61	5.93	5.71	5.50	5.28	5.09	4.91	4.47	4.07	3.77	3.46	2.98	2.62	1.99	1.51	0.62	0.38	0.21	1.23	253.4	243.6	4.97	2.39	0.91
.030	6.72	6.04	5.82	5.61	5.39	5.20	5.01	4.57	4.17	3.86	3.55	3.06	2.69	2.07	1.60	0.66	0.41	0.23	1.26	265.6	258.3	5.04	2.38	0.98
.032	6.83	6.16	5.93	5.72	5.50	5.30	5.11	4.66	4.27	3.94	3.65	3.14	2.76	2.14	1.68	0.71	0.43	0.24	1.29	277.7	272.7	5.10	2.38	1.04
.034	6.93	6.27	6.04	5.82	5.60	5.40	5.21	4.76	4.37	4.03	3.74	3.22	2.84	2.21	1.77	0.75	0.46	0.26	1.32	289.9	287.0	5.17	2.37	1.11
.036	7.03	6.38	6.14	5.93	5.71	5.50	5.31	4.85	4.46	4.11	3.83	3.30	2.91	2.27	1.85	0.78	0.49	0.27	1.35	302.0	301.2	5.24	2.37	1.17
.038	7.14	6.49	6.25	6.04	5.82	5.60	5.41	4.94	4.56	4.19	3.91	3.40	2.99	2.32	1.92	0.83	0.51	0.29	1.37	314.2	315.2	5.30	2.36	1.24
.040	7.24	6.60	6.36	6.14	5.92	5.70	5.51	5.03	4.65	4.27	4.00	3.46	3.06	2.38	1.99	0.87	0.54	0.30	1.40	326.3	329.1	5.37	2.36	1.30
.042	7.35	6.72	6.47	6.25	6.03	5.80	5.61	5.12	4.74	4.35	4.08	3.52	3.13	2.49	2.05	0.91	0.56	0.32	1.43	338.5	342.9	5.44	2.35	1.36
.044	7.46	6.83	6.58	6.35	6.13	5.90	5.71	5.22	4.83	4.43	4.16	3.59	3.20	2.59	2.10	0.95	0.59	0.33	1.45	350.6	356.6	5.50	2.35	1.43
.046	7.58	6.94	6.69	6.46	6.23	6.01	5.80	5.32	4.92	4.53	4.24	3.68	3.27	2.65	2.15	0.99	0.62	0.35	1.48	362.8	370.2	5.57	2.34	1.49
.048	7.70	7.05	6.80	6.56	6.34	6.11	5.90	5.42	5.01	4.62	4.32	3.77	3.34	2.71	2.19	1.03	0.64	0.36	1.50	374.9	383.7	5.64	2.33	1.56
.050	7.82	7.16	6.91	6.66	6.44	6.21	6.00	5.51	5.10	4.71	4.39	3.85	3.40	2.77	2.23	1.07	0.67	0.38	1.52	387.1	397.1	5.70	2.33	1.62
.052	7.94	7.27	7.02	6.77	6.54	6.31	6.09	5.61	5.18	4.80	4.47	3.88	3.47	2.83	2.27	1.11	0.69	0.39	1.55	399.2	410.4	5.77	2.32	1.69
.054	8.06	7.38	7.13	6.87	6.64	6.41	6.18	5.70	5.27	4.88	4.54	3.96	3.53	2.89	2.30	1.15	0.72	0.41	1.57	411.4	423.6	5.84	2.32	1.75
.056	8.18	7.49	7.23	6.97	6.75	6.52	6.28	5.80	5.35	4.97	4.61	4.03	3.60	2.95	2.37	1.18	0.74	0.42	1.59	423.5	436.8	5.90	2.31	1.82
.058	8.30	7.60	7.34	7.08	6.85	6.62	6.38	5.89	5.44	5.06	4.68	4.10	3.68	3.01	2.47	1.22	0.77	0.44	1.62	435.7	449.9	5.97	2.31	1.88
.060	8.43	7.71	7.45	7.18	6.95	6.72	6.48	5.98	5.52	5.14	4.75	4.18	3.74	3.07	2.57	1.26	0.79	0.45	1.64	447.8	462.9	6.04	2.30	1.95
.062	8.55	7.82	7.56	7.29	7.05	6.82	6.58	6.07	5.60	5.22	4.82	4.25	3.79	3.10	2.65	1.30	0.82	0.47	1.66	460.0	475.9	6.10	2.30	2.01
.064	8.67	7.93	7.66	7.40	7.15	6.92	6.68	6.17	5.69	5.31	4.91	4.32	3.84	3.16	2.68	1.34	0.85	0.48	1.68	472.1	488.8	6.17	2.29	2.08
.066	8.79	8.04	7.77	7.50	7.25	7.02	6.77	6.26	5.77	5.39	4.99	4.39	3.92	3.22	2.73	1.38	0.87	0.50	1.70	484.3	501.7	6.24	2.29	2.14
.068	8.91	8.14	7.88	7.61	7.35	7.12	6.87	6.35	5.85	5.47	5.08	4.46	3.99	3.27	2.78	1.41	0.90	0.51	1.73	496.4	514.5	6.30	2.28	2.21
.070	9.03	8.25	7.99	7.71	7.45	7.21	6.97	6.44	5.93	5.56	5.16	4.53	4.07	3.33	2.83	1.45	0.92	0.53	1.75	508.6	527.2	6.37	2.28	2.27
.072	9.15	8.37	8.09	7.82	7.55	7.31	7.07	6.53	6.01	5.64	5.24	4.60	4.10	3.38	2.88	1.49	0.95	0.54	1.77	520.7	539.9	6.44	2.27	2.33
.074	9.27	8.49	8.20	7.92	7.65	7.41	7.17	6.62	6.10	5.72	5.32	4.67	4.16	3.44	2.93	1.52	0.97	0.55	1.79	532.9	552.5	6.50	2.27	2.40
.076	9.39	8.61	8.31	8.03	7.75	7.51	7.26	6.71	6.19	5.80	5.40	4.74	4.23	3.49	2.96	1.56	1.00	0.57	1.81	545.0	565.1	6.57	2.26	2.46
.078	9.51	8.73	8.41	8.13	7.85	7.61	7.36	6.80	6.28	5.88	5.49	4.81	4.29	3.55	3.01	1.60	1.02	0.58	1.83	557.2	577.7	6.64	2.25	2.53
.080	9.63	8.85	8.52	8.24	7.95	7.71	7.46	6.89	6.37	5.96	5.56	4.88	4.35	3.60	3.05	1.63	1.05	0.60	1.85	569.3	590.2	6.70	2.25	2.59

5. Calculate d, using values found in far right column of Table 6.6A as follows: Assume a value of γ.*	0.75
Calculate $p_g = (1 + \gamma)p$.† Using table, read (by interpolating if necessary) $(M_u/bt^2)_{Table}$ (ksi). Calculate:	0.175 0.37
$t = \{L^2q/[8000\ (M_u/bt^2)_{Table}]\}^{0.5}$	14.50
$d = (1 + \gamma)t/2$	12.69
6. Using Eq. 6-4, calculate T(sec), then recalculate t_{oo}/T.[81]	0.03845 18.47
7. Repeat Steps 4, 5 and 6 as necessary, until d predicted in Step 5 does not change appreciably.	12.69(last trial)
8. Estimate in-plane vertical load P_u(kips); minimum would be $P_u = 2L(2p_{so})$‡ (used in this example), to which could be added weights of slab and wall above.	8.64
9. Calculate T(sec) using Eq. 6-4, with latest value of d (from Step 7 or 13). Recalculate t_{oo}/T.	0.03845 18.5
10. Using Figure 6-1, page 11-5, read p_m/q (as before); calculate q, using $p_m = p_{so}$.	0.50 30
11. Using p_g and γ (at or closest to γ available) in table, find t_e/t.§ Calculate t_e then L/t_e. Calculate A_g (=bt), then P_u/A_g. Find δ from moment multiplier table.	0.0175;0.75; 1.11;16.10;8.94; 14.50;0.60;1.05

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* Assume $\gamma = 0.75$ for first trial; if this varies significantly from the value found in Step 15, assume a corrected value of γ and repeat the entire procedure. See figure on Table 6.6A for meaning of γ.

† In use, $p_g = (A_s + A_s') / A_g = 2A_s / A_g$.

‡ In this step only, L is half the supported slab clear span on each side of wall (average if different). For an explanation of P_u calculation, see fourth paragraph, page 6-84.[81] L = 144 in. was used, unfortunately, in this and other examples.

§ If more accuracy is desired, interpolate linearly between tabular values; also, if γ is not covered by a particular table, interpolate between tables showing γ values above and below the value desired.

12. Calculate $M_u = \delta q L^2/8$ (in.-kips). Calculate $(\delta e) = M_u/P_u$ then $(\delta e)/t$. Find P_u/A_g from table; if greater than or equal to P_u/A_g calculated in Step 11 <u>and</u> it is first time this step has been performed, go to Step 14.	81648; 9.45;0.65;1.28; 0.60 (Go to Step 14)
13. Calculate a new t: $$t_{new} = 0.5\ (t_{previous})\ \{1+[P_u A_{g_{Calc'd}} \div P_u/A_{g_{Table}}]^{0.5}\}$$ Repeat Steps 8 through 13 until $t_{new} \approx t_{previous}$.	
14. Using latest values of t and d, calculate web steel needed for diagonal tension; check for pure shear and bond; all as described in Step 7 of Final Design Procedure above.[81] (Results are of Eq. 6-9a, 6-9b, 6-10 and 6-11 calculations; Eq. 6-12 not used, because steel not detailed.)[81]	14.50;12.69*; q=30>16.89;min.p_v=0.005; q=30>21.6;calc'd p_v=0.011;p_m=15<78; V=1080;v=V/bt=0.025f'_c

15. Calculate $A_s = A'_s$ = pbd; then select size(s) and spacing of main rebars. Calculate $A_v = p_v sb$; then select size and spacing of special stirrups.† Determine value of γ (ratio of c-c main rebar dimension to wall thickness t; see drawing at top of each left page, Table 6.6A). Compare this γ with value assumed in Step 5 and, if they vary significantly (say, about 6-10% or more), repeat design procedure from Step 5 onward, using a new assumed value of γ (one just found in this step might be best).

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* By longer final design method, d = 12.66; this slight difference can be attributed to round-offs made in various design steps.

† See text formula just below Eq. 6-9b.[81]

In general it was found that, for small vertical loads, the vertical load increases the moment capacity. Only when the vertical load is very large does it reduce moment carrying capacity. Both Final Design Procedures (herein and in Ref. 81) lead to the more conservative design, as between using $P_u = 0$ and P_u as estimated in Step 8.

Alternate Final Design Procedure. This procedure is no more elaborate - in fact, it is closely like - the preliminary design procedure,* yet is equal in precision to the above final design procedure.[81] The distinction among the three procedures is that this one is limited to design parameters encompassed by Table 6.7A; the others are not so limited. Table 6.7A will handle only values of f_{dy} = 52 or 72 ksi, and f'_c = 3, 4 or 5 ksi. It will also handle specific values of γ = 0.45, 0.6, 0.75 and 0.9. For other γ values, use of the nearest one should be adequate; if not, two designs may be developed using tabulated γ values above and below the desired value, then an interpolated design may be used.

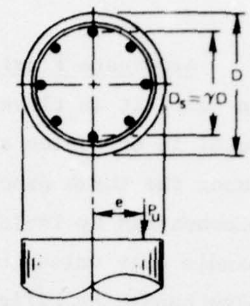
The program was tested by calculating one circular column interaction table comparable to those prepared by ACI[67] and CRSI,[69] then comparing tabular values; results were excellent.

Shown below are both the steps of this alternate final design procedure and an example problem, the same circular column design problem used in the final and preliminary design procedure examples.*

		2nd trial	3rd trial
1. Given values for: f'_c and f'_{dc}(ksi); f_y and f_{dy}(ksi); p_{so} (psi); P_u(kips)†; L(in.); p (ρ used in Ref. 67).‡	3;3.75;40;52 15;3.11;144;0.04		
2. Assume code minimum eccentricity, e = 0.05 D or 1 in., whichever is larger§ (use first trial D = 12 in.**); assume moment magnifier δ = 1.1;** assume D_s/D (= γ) = 0.75;** see Figure 6-9 (note Ref. 67 uses h for the D herein).[81]	1 12 1.1 0.75		
3. Calculate $\delta e/D$ and use γ and p_g(=p); find $(P_u/A_g)_{Table}$(ksi) in Table 6.7A (6.7A.1 for this example).	0.09 4.04	0.38 1.98	0.12 3.73

* Appendix G - Supplement.[81]
† For values of P_u and μ, see Step 1 of final design procedure just above.[81]
‡ For guidance, see second subsection above, Selecting Column Steel Ratio.[81]
§ Or even larger, if indicated by experience.
** Unless otherwise indicated by experience.

Table 6.7A.1 Values of ultimate axial stress, P_u/A_g, for circular column, f'_c = 3 ksi, f_{dy} = 52 ksi, γ = 0.45, 0.60, 0.75, 0.90



VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .45

p_g Steel Ratio	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at ϵ_s=0	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO $\delta e/D$																					
.010	3.23	2.77	2.58	2.40	2.22	2.06	1.90	1.58	1.27	1.09	0.91	0.66	0.50	0.33	0.25	0.11	0.07	0.04	1.00	35.4	2.35	1.25
.012	3.31	2.83	2.64	2.45	2.27	2.11	1.94	1.62	1.32	1.13	0.94	0.70	0.55	0.37	0.27	0.12	0.08	0.04	1.00	36.6	2.41	1.25
.014	3.39	2.89	2.70	2.50	2.31	2.15	1.98	1.67	1.38	1.17	0.98	0.75	0.58	0.40	0.30	0.13	0.09	0.05	1.00	37.8	2.47	1.25
.016	3.47	2.95	2.75	2.55	2.36	2.20	2.02	1.71	1.43	1.21	1.03	0.77	0.62	0.43	0.32	0.14	0.09	0.05	1.00	39.0	2.52	1.24
.018	3.55	3.02	2.81	2.60	2.41	2.24	2.06	1.75	1.43	1.23	1.07	0.81	0.64	0.45	0.35	0.16	0.10	0.06	1.00	40.2	2.58	1.24
.020	3.63	3.08	2.86	2.65	2.45	2.28	2.11	1.74	1.46	1.26	1.10	0.84	0.67	0.47	0.36	0.17	0.11	0.06	1.00	41.4	2.64	1.23
.022	3.71	3.14	2.92	2.70	2.50	2.33	2.15	1.78	1.50	1.28	1.14	0.87	0.70	0.50	0.38	0.18	0.11	0.07	1.00	42.6	2.70	1.23
.024	3.79	3.20	2.98	2.75	2.55	2.37	2.19	1.82	1.54	1.34	1.17	0.91	0.73	0.51	0.40	0.18	0.12	0.07	1.00	43.8	2.75	1.22
.026	3.87	3.26	3.03	2.80	2.59	2.42	2.23	1.86	1.57	1.34	1.19	0.93	0.75	0.54	0.42	0.19	0.13	0.07	1.00	45.0	2.81	1.22
.028	3.94	3.32	3.09	2.85	2.64	2.46	2.28	1.89	1.61	1.38	1.22	0.96	0.78	0.56	0.43	0.20	0.13	0.08	1.00	46.2	2.87	1.22
.030	4.02	3.38	3.14	2.90	2.69	2.51	2.32	1.93	1.65	1.41	1.25	0.99	0.80	0.58	0.45	0.21	0.14	0.08	1.00	47.3	2.93	1.21
.032	4.10	3.44	3.20	2.95	2.74	2.55	2.36	1.97	1.68	1.44	1.26	1.02	0.83	0.60	0.46	0.22	0.14	0.08	1.00	48.5	2.98	1.21
.034	4.18	3.50	3.25	3.00	2.78	2.60	2.40	2.00	1.72	1.48	1.30	1.04	0.85	0.62	0.48	0.23	0.15	0.09	1.00	49.7	3.04	1.20
.036	4.26	3.56	3.31	3.05	2.83	2.64	2.44	2.04	1.76	1.51	1.31	1.07	0.87	0.64	0.50	0.23	0.15	0.09	1.00	50.9	3.10	1.20
.038	4.34	3.61	3.37	3.10	2.88	2.69	2.49	2.08	1.79	1.54	1.34	1.09	0.90	0.65	0.51	0.24	0.16	0.09	1.00	52.1	3.16	1.19
.040	4.41	3.67	3.42	3.14	2.93	2.73	2.53	2.11	1.79	1.58	1.37	1.11	0.92	0.67	0.53	0.25	0.16	0.10	1.00	53.3	3.21	1.19
.042	4.49	3.73	3.48	3.19	2.97	2.78	2.57	2.15	1.82	1.58	1.40	1.14	0.94	0.69	0.54	0.26	0.17	0.10	1.00	54.5	3.27	1.18
.044	4.57	3.80	3.53	3.24	3.02	2.82	2.61	2.19	1.86	1.61	1.43	1.16	0.96	0.71	0.55	0.26	0.17	0.10	1.00	55.7	3.33	1.18
.046	4.65	3.86	3.59	3.29	3.07	2.87	2.66	2.22	1.89	1.64	1.46	1.18	0.98	0.72	0.57	0.27	0.18	0.11	1.00	56.9	3.39	1.18
.048	4.73	3.92	3.64	3.34	3.12	2.91	2.70	2.26	1.92	1.67	1.49	1.20	1.00	0.74	0.58	0.28	0.18	0.11	1.00	58.1	3.45	1.17
.050	4.80	3.98	3.70	3.39	3.16	2.96	2.74	2.29	1.96	1.70	1.49	1.23	1.03	0.76	0.60	0.29	0.19	0.11	1.00	59.3	3.50	1.17
.052	4.88	4.04	3.75	3.43	3.21	3.00	2.78	2.33	1.99	1.73	1.52	1.23	1.03	0.76	0.60	0.29	0.19	0.11	1.01	60.5	3.56	1.16
.054	4.96	4.10	3.81	3.48	3.26	3.05	2.82	2.36	2.03	1.76	1.55	1.25	1.04	0.78	0.62	0.30	0.20	0.12	1.02	61.7	3.62	1.16
.056	5.04	4.16	3.86	3.53	3.31	3.09	2.87	2.40	2.06	1.79	1.57	1.27	1.06	0.79	0.63	0.30	0.20	0.12	1.03	62.9	3.68	1.15
.058	5.12	4.22	3.92	3.58	3.36	3.14	2.91	2.43	2.09	1.82	1.60	1.29	1.08	0.81	0.64	0.31	0.20	0.12	1.04	64.0	3.73	1.15
.060	5.19	4.28	3.97	3.63	3.40	3.18	2.95	2.47	2.13	1.85	1.63	1.31	1.10	0.83	0.65	0.32	0.21	0.12	1.05	65.2	3.79	1.15
.062	5.27	4.34	4.03	3.67	3.45	3.23	2.99	2.50	2.16	1.88	1.66	1.34	1.12	0.84	0.67	0.32	0.21	0.13	1.06	66.4	3.85	1.14
.064	5.35	4.40	4.08	3.72	3.50	3.27	3.04	2.54	2.19	1.92	1.68	1.36	1.14	0.85	0.68	0.33	0.22	0.13	1.07	67.6	3.91	1.14
.066	5.43	4.46	4.14	3.77	3.55	3.32	3.08	2.57	2.23	1.92	1.71	1.39	1.15	0.87	0.69	0.34	0.22	0.13	1.08	68.8	3.96	1.13
.068	5.50	4.53	4.19	3.82	3.59	3.37	3.12	2.61	2.23	1.94	1.74	1.39	1.17	0.88	0.70	0.34	0.23	0.13	1.09	70.0	4.02	1.13
.070	5.58	4.59	4.25	3.86	3.64	3.41	3.16	2.64	2.26	1.97	1.74	1.41	1.19	0.90	0.71	0.35	0.23	0.14	1.10	71.2	4.08	1.12
.072	5.66	4.65	4.30	3.91	3.69	3.46	3.21	2.68	2.29	2.00	1.77	1.44	1.20	0.91	0.73	0.36	0.23	0.14	1.11	72.4	4.14	1.12
.074	5.73	4.71	4.35	3.96	3.74	3.50	3.25	2.71	2.32	2.03	1.80	1.46	1.22	0.93	0.74	0.36	0.24	0.14	1.12	73.6	4.20	1.11
.076	5.81	4.77	4.41	4.01	3.79	3.55	3.29	2.75	2.36	2.06	1.82	1.48	1.24	0.94	0.75	0.37	0.24	0.14	1.13	74.8	4.25	1.11
.078	5.89	4.83	4.46	4.06	3.83	3.59	3.33	2.78	2.39	2.09	1.85	1.50	1.26	0.96	0.76	0.37	0.25	0.15	1.14	76.0	4.31	1.11
.080	5.97	4.89	4.52	4.11	3.88	3.64	3.37	2.81	2.42	2.12	1.87	1.53	1.28	0.97	0.78	0.38	0.25	0.15	1.14	77.2	4.37	1.10

VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6

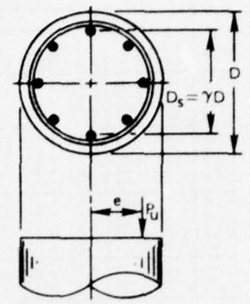
p_g Steel Ratio	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at ϵ_s=0	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO $\delta e/D$																					
.010	3.24	2.80	2.62	2.45	2.28	2.13	1.99	1.66	1.39	1.18	1.00	0.72	0.54	0.35	0.26	0.11	0.07	0.04	1.00	40.1	2.62	1.50
.012	3.32	2.87	2.68	2.51	2.34	2.19	2.05	1.71	1.46	1.23	1.04	0.78	0.60	0.40	0.30	0.13	0.08	0.05	1.00	42.2	2.68	1.51
.014	3.40	2.93	2.74	2.57	2.40	2.24	2.10	1.76	1.51	1.28	1.10	0.84	0.65	0.44	0.33	0.14	0.09	0.05	1.00	44.3	2.74	1.52
.016	3.48	3.00	2.80	2.63	2.46	2.29	2.16	1.81	1.57	1.34	1.18	0.88	0.70	0.48	0.36	0.16	0.10	0.06	1.00	46.4	2.81	1.53
.018	3.56	3.07	2.87	2.70	2.51	2.35	2.21	1.86	1.63	1.39	1.22	0.93	0.74	0.51	0.39	0.17	0.11	0.06	1.00	48.5	2.87	1.54
.020	3.64	3.14	2.93	2.76	2.57	2.40	2.27	1.90	1.68	1.45	1.25	0.98	0.77	0.55	0.41	0.18	0.12	0.07	1.00	50.7	2.93	1.55
.022	3.72	3.21	2.99	2.82	2.63	2.45	2.32	1.96	1.73	1.50	1.29	1.03	0.82	0.58	0.44	0.20	0.13	0.07	1.00	52.8	2.99	1.56
.024	3.80	3.28	3.06	2.88	2.69	2.51	2.37	2.01	1.77	1.55	1.35	1.07	0.85	0.60	0.46	0.21	0.13	0.08	1.00	54.9	3.05	1.57
.026	3.88	3.34	3.12	2.94	2.74	2.56	2.43	2.06	1.82	1.56	1.40	1.11	0.89	0.63	0.49	0.22	0.14	0.08	1.00	57.0	3.12	1.58
.028	3.96	3.41	3.18	3.00	2.80	2.61	2.48	2.12	1.86	1.60	1.45	1.15	0.93	0.67	0.51	0.23	0.15	0.09	1.00	59.1	3.18	1.59
.030	4.04	3.48	3.24	3.06	2.86	2.66	2.53	2.17	1.90	1.64	1.46	1.18	0.97	0.69	0.53	0.25	0.16	0.09	1.02	61.3	3.24	1.60
.032	4.12	3.55	3.31	3.12	2.92	2.72	2.58	2.22	1.94	1.69	1.50	1.21	0.99	0.72	0.56	0.26	0.17	0.10	1.04	63.4	3.30	1.61
.034	4.21	3.62	3.37	3.18	2.98	2.77	2.63	2.27	1.98	1.73	1.54	1.24	1.03	0.74	0.58	0.27	0.17	0.10	1.05	65.5	3.36	1.62
.036	4.29	3.68	3.43	3.24	3.03	2.82	2.69	2.33	2.02	1.77	1.57	1.28	1.06	0.77	0.60	0.28	0.18	0.11	1.07	67.6	3.43	1.63
.038	4.37	3.75	3.50	3.30	3.09	2.87	2.74	2.38	2.06	1.81	1.61	1.32	1.09	0.80	0.62	0.29	0.19	0.11	1.09	69.7	3.49	1.64
.040	4.45	3.82	3.56	3.36	3.15	2.92	2.79	2.43	2.10	1.85	1.65	1.34	1.13	0.83	0.65	0.30	0.20	0.12	1.10	71.9	3.55	1.65
.042	4.53	3.89	3.62	3.42	3.21	2.98	2.84	2.48	2.13	1.89	1.69	1.37	1.15	0.85	0.67	0.31	0.20	0.12	1.12	74.0	3.61	1.66
.044	4.61	3.96	3.69	3.48	3.26	3.03	2.89	2.46	2.17	1.93	1.73	1.41	1.19	0.88	0.68	0.32	0.21	0.12	1.14	76.1	3.67	1.67
.046	4.69	4.03	3.75	3.54	3.32	3.09	2.94	2.51	2.20	1.97	1.77	1.44	1.22	0.90	0.71	0.33	0.22	0.13	1.15	78.2	3.74	1.68
.048	4.77	4.09	3.81	3.60	3.38	3.14	2.99	2.56	2.24	2.01	1.80	1.47	1.23	0.92	0.73	0.34	0.22	0.13	1.17	80.3	3.80	1.69
.050	4.85	4.16	3.87	3.66	3.44	3.19	3.04	2.60	2.27	2.05	1.84	1.51	1.27	0.95	0.75	0.35	0.23	0.14	1.18	82.5	3.86	1.70
.052	4.93	4.23	3.94	3.72	3.49	3.25	3.09	2.65	2.32	2.09	1.88	1.54	1.29	0.97	0.77	0.36	0.24	0.14	1.20	84.6	3.92	1.71
.054	5.01	4.30	4.00	3.78	3.55	3.30	3.14	2.70	2.37	2.13	1.92	1.57	1.31	0.99	0.78	0.38	0.24	0.14	1.21	86.7	3.99	1.72
.056	5.09	4.37	4.06	3.84	3.61	3.36	3.19	2.74	2.42	2.16	1.96	1.61	1.34	1.02	0.80	0.38	0.25	0.15	1.23	88.8	4.05	1.73
.058	5.17	4.43	4.13	3.90	3.67	3.41	3.24	2.79	2.46	2.20	1.96	1.64	1.37	1.04	0.82	0.39	0.26	0.15	1.24	90.9	4.11	1.74
.060	5.25	4.50	4.19	3.96	3.72	3.47	3.29	2.83	2.51	2.24	2.00	1.67	1.40	1.06	0.84	0.41	0.27	0.16	1.26	93.1	4.17	1.75
.062	5.34	4.57	4.25	4.02	3.78	3.52	3.34	2.88	2.56	2.27	2.03	1.70	1.43	1.08	0.86	0.41	0.27	0.16	1.27	95.2	4.23	1.76
.064	5.42	4.64	4.32	4.08	3.84	3.57	3.39	2.93	2.60	2.31	2.07	1.73	1.46	1.10	0.88	0.42	0.28	0.16	1.29	97.3	4.30	1.77
.066	5.50	4.71	4.38	4.14	3.89	3.63	3.44	2.97	2.65	2.35	2.10	1.77	1.49	1.13	0.90	0.43	0.29	0.17	1.30	99.4	4.36	1.78
.068	5.58	4.78	4.44	4.20	3.95	3.68	3.49	3.02	2.70	2.38	2.14	1.77	1.52	1.15	0.91	0.44	0.29	0.17	1.31	101.6	4.42	1.79
.070	5.66	4.84	4.51	4.26	4.01	3.74	3.54	3.06	2.68	2.42	2.17	1.80	1.55	1.17	0.93	0.45	0.30	0.18	1.33	103.7	4.48	1.79
.072	5.74	4.91	4.57	4.32	4.07	3.79	3.59	3.11	2.72	2.45	2.21	1.83	1.56	1.21	1.07	0.53	0.35	0.21	1.34	105.8	4.54	1.80
.074	5.82	4.98	4.63	4.38	4.12	3.85	3.64	3.15	2.76	2.49	2.24	1.86	1.58	1.20	0.96	0.47	0.31	0.18	1.35	107.9	4.61	1.81
.076	5.90	5.05	4.69	4.44	4.18	3.90	3.69	3.20	2.80	2.52	2.28	1.89	1.61	1.23	0.98	0.48	0.32	0.19	1.37	110.0	4.67	1.82
.078	5.98	5.12	4.76	4.50	4.24	3.95	3.74	3.24	2.84	2.58	2.31	1.92	1.64	1.24	1.00	0.49	0.32	0.19	1.38	112.2	4.73	1.83
.080	6.06	5.18	4.82	4.56	4.30	4.01	3.79	3.29	2.88	2.61	2.35	1.95	1.66	1.26	1.01	0.50	0.33	0.20	1.39	114.3	4.79	1.84

L/D_e	VALUES OF MOMENT MULTIPLIERS δ — VALUES OF ULTIMATE STRESS P_u/A_g IN KSI 0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04
3.0	1.00	1.00	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.09
4.0	1.00	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.05	1.06	1.06	1.07	1.08	1.09	1.11	1.12	1.13	1.15	1.16
5.0	1.01	1.01	1.02	1.03	1.03	1.04	1.05	1.06	1.06	1.07	1.08	1.09	1.10	1.10	1.11	1.13	1.16	1.18	1.20	1.23	1.25	1.28
6.0	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.10	1.11	1.12	1.13	1.14	1.16	1.17	1.21	1.24	1.28	1.32	1.37	1.41	1.46
7.0	1.01	1.03	1.04	1.06	1.07	1.09	1.10	1.12	1.14	1.15	1.17	1.19	1.21	1.23	1.25	1.30	1.36	1.42	1.49	1.57	1.66	1.76
8.0	1.02	1.04	1.05	1.07	1.09	1.12	1.14	1.16	1.18	1.21	1.23	1.26	1.29	1.32	1.35	1.43	1.53	1.64	1.76	1.91	2.08	2.28
9.0	1.02	1.05	1.07	1.10	1.12	1.15	1.18	1.21	1.25	1.28	1.32	1.36	1.40	1.44	1.49	1.62	1.78	1.97	2.21	2.51	2.91	3.46
10.0	1.03	1.06	1.09	1.12	1.16	1.19	1.23	1.28	1.32	1.37	1.42	1.48	1.54	1.61	1.68	1.90	2.18	2.55	3.08	3.89	5.28	8.20
11.0	1.03	1.07	1.11	1.15	1.20	1.24	1.30	1.35	1.42	1.49	1.56	1.65	1.74	1.84	1.96	2.34	2.89	3.78	5.47	9.91		
12.0	1.04	1.08	1.13	1.18	1.24	1.30	1.37	1.45	1.54	1.64	1.75	1.88	2.02	2.20	2.40	3.13	4.51	8.03				
13.0	1.05	1.10	1.16	1.22	1.30	1.38	1.47	1.58	1.70	1.84	2.01	2.21	2.46	2.77	3.17	4.98						
14.0	1.06	1.12	1.19	1.27	1.36	1.47	1.59	1.74	1.91	2.13	2.40	2.74	3.21	3.87	4.86							
15.0	1.06	1.14	1.22	1.32	1.44	1.57	1.74	1.95	2.21	2.55	3.02	3.70	4.77	6.72								
16.0	1.07	1.16	1.26	1.38	1.53	1.71	1.94	2.24	2.65	3.24	4.18	5.88	9.92									
17.0	1.08	1.19	1.31	1.45	1.64	1.88	2.21	2.66	3.36	4.56	7.09											
18.0	1.10	1.21	1.36	1.54	1.78	2.11	2.58	3.34	4.71	8.03												

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .75 — VALUES OF ECCENTRICITY RATIO $\delta e/D$ 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
.010	3.25	2.83	2.66	2.50	2.35	2.19	2.07	1.75	1.49	1.26	1.08	0.78	0.60	0.39	0.29	0.12	0.07	0.04	1.00	46.0	2.87	1.71
.012	3.33	2.90	2.73	2.57	2.42	2.26	2.13	1.83	1.56	1.33	1.16	0.85	0.66	0.44	0.32	0.14	0.09	0.05	1.00	49.3	2.93	1.73
.014	3.41	2.98	2.80	2.64	2.49	2.33	2.19	1.90	1.63	1.40	1.22	0.91	0.72	0.49	0.36	0.16	0.10	0.06	1.00	52.6	3.00	1.75
.016	3.50	3.05	2.88	2.71	2.55	2.40	2.26	1.96	1.69	1.47	1.27	0.98	0.78	0.53	0.40	0.17	0.11	0.06	1.00	56.0	3.06	1.77
.018	3.58	3.13	2.95	2.77	2.62	2.46	2.31	2.03	1.75	1.54	1.33	1.04	0.82	0.58	0.44	0.19	0.12	0.07	1.00	59.3	3.13	1.78
.020	3.66	3.20	3.02	2.84	2.69	2.53	2.37	2.09	1.80	1.60	1.40	1.09	0.88	0.62	0.47	0.21	0.13	0.08	1.03	62.6	3.19	1.80
.022	3.75	3.27	3.09	2.90	2.75	2.60	2.43	2.15	1.86	1.65	1.46	1.15	0.93	0.66	0.50	0.22	0.14	0.08	1.06	65.9	3.26	1.82
.024	3.83	3.35	3.16	2.97	2.82	2.66	2.49	2.21	1.93	1.70	1.52	1.21	0.98	0.70	0.53	0.24	0.15	0.09	1.08	69.2	3.32	1.84
.026	3.92	3.42	3.23	3.03	2.88	2.73	2.56	2.27	1.99	1.75	1.57	1.24	1.03	0.73	0.56	0.25	0.16	0.09	1.11	72.5	3.38	1.85
.028	4.00	3.49	3.30	3.10	2.95	2.79	2.62	2.33	2.05	1.80	1.63	1.29	1.06	0.77	0.59	0.27	0.17	0.10	1.13	75.8	3.45	1.87
.030	4.08	3.56	3.37	3.17	3.01	2.85	2.69	2.39	2.11	1.85	1.68	1.35	1.10	0.80	0.62	0.28	0.18	0.11	1 16	79.2	3.51	1.89
.032	4.17	3.64	3.44	3.24	3.08	2.92	2.75	2.44	2.12	1.89	1.72	1.40	1.16	0.83	0.64	0.30	0.19	0.11	1.18	82.5	3.58	1.90
.034	4.25	3.71	3.51	3.31	3.14	2.98	2.81	2.50	2.17	1.94	1.77	1.42	1.19	0.87	0.68	0.31	0.20	0.12	1.21	85.8	3.64	1.92
.036	4.33	3.78	3.59	3.37	3.20	3.04	2.87	2.55	2.22	2.00	1.81	1.46	1.23	0.90	0.70	0.33	0.21	0.12	1.23	89.1	3.71	1.94
.038	4.42	3.85	3.66	3.44	3.27	3.11	2.94	2.60	2.28	2.06	1.85	1.51	1.26	0.93	0.73	0.34	0.22	0.13	1.25	92.4	3.77	1.96
.040	4.50	3.93	3.73	3.51	3.33	3.17	3.00	2.65	2.33	2.11	1.90	1.55	1.31	0.96	0.75	0.35	0.23	0.13	1.27	95.7	3.84	1.97
.042	4.58	4.00	3.80	3.58	3.39	3.23	3.06	2.71	2.38	2.13	1.94	1.59	1.33	1.00	0.78	0.37	0.24	0.14	1.30	99.0	3.90	1.99
.044	4.66	4.07	3.87	3.65	3.46	3.29	3.12	2.76	2.43	2.17	1.98	1.64	1.37	1.03	0.81	0.38	0.25	0.15	1.32	102.3	3.97	2.01
.046	4.75	4.14	3.94	3.71	3.52	3.35	3.18	2.81	2.48	2.22	2.01	1.68	1.41	1.06	0.83	0.39	0.26	0.15	1.34	105.7	4.03	2.02
.048	4.83	4.22	4.01	3.78	3.58	3.42	3.24	2.86	2.53	2.27	2.05	1.72	1.45	1.09	0.86	0.41	0.27	0.16	1.36	109.0	4.10	2.04
.050	4.92	4.29	4.08	3.85	3.64	3.48	3.30	2.91	2.58	2.31	2.10	1.76	1.48	1.12	0.89	0.42	0.27	0.16	1.38	112.3	4.16	2.06
.052	5.00	4.36	4.15	3.92	3.70	3.54	3.36	2.96	2.63	2.36	2.15	1.80	1.52	1.15	0.91	0.43	0.28	0.17	1.40	115.6	4.23	2.08
.054	5.08	4.43	4.22	3.98	3.77	3.60	3.42	3.01	2.68	2.41	2.20	1.83	1.56	1.17	0.93	0.45	0.29	0.17	1.42	118.9	4.29	2.09
.056	5.17	4.50	4.29	4.05	3.83	3.66	3.48	3.06	2.73	2.45	2.26	1.87	1.59	1.21	0.95	0.46	0.30	0.18	1.44	122.2	4.36	2.11
.058	5.25	4.58	4.36	4.12	3.89	3.72	3.54	3.10	2.78	2.50	2.26	1.91	1.63	1.22	0.98	0.47	0.31	0.18	1.46	125.5	4.42	2.13
.060	5.34	4.65	4.43	4.19	3.95	3.78	3.60	3.15	2.83	2.55	2.30	1.95	1.67	1.25	1.00	0.48	0.32	0.19	1.48	128.9	4.49	2.15
.062	5.42	4.72	4.50	4.25	4.01	3.84	3.66	3.20	2.88	2.59	2.34	1.98	1.70	1.28	1.03	0.50	0.32	0.19	1.50	132.2	4.55	2.16
.064	5.50	4.80	4.57	4.32	4.07	3.90	3.72	3.25	2.93	2.64	2.39	2.02	1.74	1.31	1.05	0.51	0.33	0.20	1.52	135.5	4.62	2.18
.066	5.59	4.87	4.64	4.39	4.14	3.96	3.78	3.30	2.98	2.68	2.43	2.06	1.77	1.34	1.07	0.52	0.34	0.20	1.54	138.8	4.68	2.20
.068	5.67	4.95	4.70	4.46	4.20	4.02	3.84	3.34	3.02	2.73	2.47	2.09	1.81	1.37	1.10	0.53	0.35	0.21	1.55	142.1	4.75	2.21
.070	5.76	5.02	4.77	4.52	4.26	4.08	3.90	3.40	3.07	2.78	2.51	2.13	1.84	1.40	1.12	0.55	0.36	0.21	1.57	145.4	4.81	2.23
.072	5.84	5.09	4.84	4.59	4.32	4.14	3.96	3.46	3.12	2.82	2.56	2.19	1.85	1.42	1.14	0.56	0.37	0.22	1.59	148.7	4.88	2.25
.074	5.92	5.17	4.91	4.66	4.38	4.20	4.02	3.51	3.17	2.87	2.60	2.22	1.89	1.45	1.17	0.57	0.37	0.22	1.61	152.0	4.94	2.27
.076	6.01	5.24	4.98	4.72	4.44	4.26	4.08	3.57	3.22	2.91	2.64	2.25	1.92	1.47	1.19	0.58	0.38	0.23	1.62	155.4	5.00	2.28
.078	6.09	5.32	5.05	4.79	4.51	4.32	4.13	3.62	3.26	2.96	2.68	2.28	1.95	1.50	1.21	0.60	0.39	0.23	1.64	158.7	5.07	2.30
.080	6.18	5.39	5.12	4.86	4.57	4.38	4.19	3.68	3.31	3.00	2.73	2.31	1.99	1.52	1.22	0.61	0.40	0.24	1.66	162.0	5.13	2.32

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .9 — VALUES OF ECCENTRICITY RATIO $\delta e/D$ 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
.010	3.27	2.87	2.71	2.55	2.41	2.27	2.13	1.84	1.58	1.34	1.16	0.85	0.65	0.43	0.31	0.13	0.08	0.05	1.00	53.3	3.09	1.92
.012	3.36	2.94	2.79	2.63	2.49	2.35	2.21	1.92	1.66	1.43	1.23	0.94	0.73	0.48	0.36	0.15	0.09	0.05	1.00	58.1	3.16	1.94
.014	3.44	3.02	2.87	2.71	2.56	2.43	2.29	2.00	1.73	1.52	1.31	1.00	0.79	0.54	0.40	0.17	0.11	0.06	1.03	62.9	3.22	1.96
.016	3.53	3.10	2.95	2.78	2.64	2.50	2.37	2.07	1.81	1.59	1.39	1.07	0.86	0.59	0.44	0.19	0.12	0.07	1.07	67.6	3.29	1.98
.018	3.62	3.18	3.02	2.86	2.71	2.58	2.44	2.14	1.88	1.66	1.47	1.14	0.92	0.64	0.49	0.21	0.13	0.08	1.11	72.4	3.36	2.00
.020	3.71	3.26	3.10	2.94	2.78	2.65	2.51	2.21	1.95	1.72	1.54	1.22	0.98	0.69	0.52	0.23	0.15	0.08	1.14	77.2	3.42	2.03
.022	3.79	3.34	3.17	3.01	2.84	2.72	2.59	2.27	2.02	1.78	1.60	1.26	1.04	0.74	0.56	0.25	0.16	0.09	1.18	81.9	3.49	2.05
.024	3.88	3.42	3.25	3.09	2.92	2.79	2.66	2.33	2.08	1.85	1.66	1.33	1.09	0.77	0.60	0.27	0.17	0.10	1.21	86.7	3.56	2.07
.026	3.97	3.50	3.32	3.16	2.99	2.85	2.72	2.39	2.15	1.91	1.72	1.40	1.14	0.82	0.64	0.29	0.18	0.11	1.25	91.5	3.62	2.09
.028	4.05	3.58	3.40	3.24	3.06	2.92	2.79	2.45	2.21	1.97	1.77	1.43	1.19	0.87	0.67	0.30	0.19	0.11	1.28	96.3	3.69	2.11
.030	4.14	3.65	3.47	3.31	3.14	2.99	2.86	2.52	2.27	2.03	1.82	1.49	1.24	0.90	0.70	0.32	0.21	0.12	1.31	101.0	3.76	2.14
.032	4.22	3.73	3.55	3.38	3.21	3.05	2.93	2.59	2.33	2.09	1.88	1.54	1.29	0.94	0.73	0.34	0.22	0.13	1.34	105.8	3.82	2.16
.034	4.31	3.81	3.62	3.46	3.28	3.12	2.99	2.65	2.39	2.15	1.94	1.59	1.35	0.98	0.77	0.36	0.23	0.13	1.37	110.6	3.89	2.18
.036	4.40	3.89	3.69	3.53	3.35	3.18	3.06	2.72	2.44	2.21	1.99	1.64	1.38	1.02	0.80	0.37	0.24	0.14	1.40	115.3	3.96	2.20
.038	4.48	3.97	3.77	3.60	3.43	3.24	3.12	2.79	2.50	2.27	2.05	1.69	1.42	1.06	0.83	0.39	0.25	0.15	1.43	120.1	4.02	2.23
.040	4.57	4.05	3.84	3.67	3.50	3.31	3.18	2.85	2.55	2.33	2.11	1.74	1.47	1.10	0.87	0.40	0.26	0.15	1.46	124.9	4.09	2.25
.042	4.65	4.13	3.91	3.74	3.57	3.38	3.25	2.92	2.60	2.38	2.16	1.81	1.51	1.14	0.89	0.42	0.27	0.16	1.48	129.6	4.16	2.27
.044	4.74	4.20	3.99	3.82	3.64	3.45	3.31	2.98	2.66	2.44	2.21	1.85	1.56	1.17	0.92	0.44	0.28	0.17	1.51	134.4	4.22	2.29
.046	4.82	4.28	4.06	3.89	3.71	3.52	3.37	3.04	2.71	2.49	2.27	1.89	1.60	1.21	0.96	0.45	0.29	0.17	1.54	139.2	4.29	2.31
.048	4.91	4.36	4.14	3.96	3.78	3.59	3.43	3.11	2.76	2.54	2.32	1.93	1.65	1.24	0.99	0.47	0.30	0.18	1.56	144.0	4.36	2.34
.050	4.99	4.44	4.21	4.03	3.85	3.66	3.49	3.17	2.81	2.60	2.37	1.97	1.69	1.27	1.02	0.49	0.31	0.18	1.59	148.7	4.42	2.36
.052	5.08	4.52	4.29	4.10	3.92	3.73	3.56	3.23	2.87	2.65	2.39	2.02	1.73	1.31	1.05	0.50	0.33	0.19	1.61	153.5	4.49	2.38
.054	5.16	4.59	4.37	4.17	3.99	3.80	3.62	3.29	2.93	2.70	2.43	2.07	1.77	1.34	1.07	0.52	0.34	0.20	1.64	158.3	4.56	2.40
.056	5.25	4.67	4.44	4.24	4.06	3.87	3.68	3.35	2.99	2.75	2.48	2.12	1.81	1.38	1.11	0.53	0.35	0.20	1.66	163.0	4.62	2.42
.058	5.33	4.75	4.52	4.31	4.13	3.93	3.74	3.41	3.05	2.80	2.53	2.17	1.85	1.41	1.13	0.55	0.36	0.21	1.69	167.8	4.69	2.45
.060	5.42	4.82	4.59	4.38	4.20	4.00	3.80	3.47	3.11	2.84	2.58	2.21	1.89	1.45	1.16	0.56	0.37	0.22	1.71	172.6	4.76	2.47
.062	5.50	4.90	4.67	4.45	4.27	4.07	3.86	3.53	3.17	2.89	2.63	2.26	1.93	1.48	1.19	0.58	0.38	0.22	1.74	177.4	4.82	2.49
.064	5.58	4.98	4.74	4.52	4.33	4.14	3.93	3.59	3.23	2.94	2.68	2.31	1.97	1.52	1.21	0.59	0.39	0.23	1.76	182.1	4.89	2.51
.066	5.67	5.06	4.82	4.59	4.40	4.21	4.00	3.65	3.29	2.99	2.72	2.36	2.02	1.55	1.24	0.61	0.40	0.23	1.78	186.9	4.96	2.53
.068	5.76	5.13	4.89	4.66	4.47	4.27	4.06	3.71	3.35	3.03	2.77	2.36	2.05	1.57	1.26	0.62	0.41	0.24	1.80	191.7	5.02	2.56
.070	5.85	5.21	4.97	4.73	4.54	4.34	4.13	3.77	3.41	3.08	2.82	2.41	2.08	1.61	1.29	0.64	0.42	0.25	1.83	196.4	5.09	2.58
.072	5.93	5.29	5.04	4.80	4.61	4.41	4.19	3.82	3.47	3.12	2.87	2.45	2.12	1.64	1.32	0.65	0.43	0.25	1.85	201.2	5.16	2.60
.074	6.02	5.36	5.12	4.87	4.68	4.47	4.26	3.88	3.46	3.17	2.91	2.49	2.16	1.67	1.35	0.67	0.44	0.26	1.87	206.0	5.22	2.62
.076	6.10	5.44	5.19	4.94	4.74	4.54	4.33	3.94	3.52	3.21	2.96	2.53	2.20	1.71	1.38	0.68	0.45	0.26	1.89	210.8	5.29	2.64
.078	6.19	5.52	5.27	5.01	4.81	4.61	4.39	4.00	3.57	3.26	3.01	2.57	2.25	1.74	1.41	0.70	0.46	0.27	1.91	215.5	5.36	2.67
.080	6.28	5.59	5.34	5.08	4.88	4.68	4.46	4.05	3.62	3.31	3.05	2.61	2.29	1.77	1.43	0.71	0.47	0.28	1.93	220.3	5.42	2.69

Table 6.7A.2 Values of ultimate axial stress, P_u/A_g, for circular column, f'_c = 4 ksi, f_{dy} = 52 ksi, γ = 0.45, 0.60, 0.75, 0.90



p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .45																		Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO $\delta e/D$																					
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00				
.010	4.17	3.58	3.34	3.11	2.88	2.67	2.45	2.02	1.63	1.35	1.09	0.78	0.58	0.38	0.28	0.12	0.07	0.04	1.00	45.2	3.03	1.68
.012	4.25	3.64	3.40	3.16	2.92	2.71	2.50	2.07	1.67	1.41	1.17	0.84	0.64	0.42	0.31	0.13	0.09	0.05	1.00	46.4	3.09	1.67
.014	4.33	3.70	3.45	3.21	2.97	2.76	2.54	2.11	1.71	1.46	1.20	0.89	0.68	0.46	0.34	0.15	0.09	0.05	1.00	47.6	3.14	1.67
.016	4.40	3.76	3.51	3.26	3.01	2.80	2.58	2.16	1.76	1.51	1.25	0.94	0.73	0.49	0.37	0.16	0.10	0.06	1.00	48.8	3.20	1.66
.018	4.48	3.82	3.56	3.31	3.06	2.84	2.62	2.20	1.81	1.55	1.29	0.97	0.76	0.52	0.39	0.17	0.11	0.06	1.00	50.0	3.25	1.66
.020	4.56	3.88	3.62	3.36	3.10	2.89	2.66	2.24	1.87	1.58	1.34	1.00	0.80	0.55	0.42	0.19	0.12	0.07	1.00	51.2	3.31	1.65
.022	4.64	3.94	3.67	3.41	3.15	2.93	2.70	2.28	1.86	1.61	1.38	1.04	0.83	0.58	0.44	0.20	0.13	0.08	1.00	52.4	3.37	1.64
.024	4.71	4.00	3.73	3.46	3.20	2.98	2.74	2.32	1.90	1.64	1.42	1.08	0.85	0.60	0.46	0.21	0.13	0.08	1.00	53.6	3.42	1.64
.026	4.79	4.06	3.78	3.51	3.24	3.02	2.78	2.36	1.93	1.66	1.45	1.10	0.88	0.62	0.48	0.22	0.14	0.08	1.00	54.8	3.48	1.63
.028	4.87	4.12	3.84	3.55	3.29	3.06	2.83	2.34	1.97	1.68	1.49	1.14	0.91	0.64	0.50	0.23	0.15	0.09	1.00	56.0	3.54	1.63
.030	4.94	4.18	3.89	3.60	3.33	3.11	2.87	2.38	2.01	1.73	1.52	1.18	0.94	0.67	0.51	0.24	0.15	0.09	1.00	57.2	3.59	1.62
.032	5.02	4.24	3.95	3.65	3.38	3.15	2.91	2.41	2.04	1.78	1.55	1.21	0.97	0.69	0.53	0.25	0.16	0.09	1.00	58.4	3.65	1.62
.034	5.10	4.30	4.00	3.70	3.43	3.19	2.95	2.45	2.08	1.77	1.58	1.23	0.99	0.71	0.55	0.25	0.17	0.10	1.00	59.5	3.70	1.61
.036	5.18	4.36	4.06	3.75	3.47	3.24	2.99	2.49	2.12	1.81	1.60	1.26	1.02	0.73	0.57	0.26	0.17	0.10	1.00	60.7	3.76	1.61
.038	5.25	4.42	4.11	3.80	3.52	3.28	3.03	2.52	2.15	1.84	1.64	1.29	1.04	0.75	0.58	0.27	0.18	0.10	1.00	61.9	3.82	1.60
.040	5.33	4.48	4.17	3.84	3.56	3.33	3.07	2.56	2.19	1.87	1.65	1.31	1.07	0.77	0.60	0.28	0.18	0.11	1.00	63.1	3.87	1.60
.042	5.41	4.53	4.22	3.89	3.61	3.37	3.11	2.60	2.22	1.90	1.66	1.34	1.09	0.79	0.61	0.29	0.19	0.11	1.00	64.3	3.93	1.59
.044	5.48	4.59	4.27	3.94	3.66	3.41	3.16	2.63	2.26	1.94	1.70	1.37	1.12	0.81	0.63	0.30	0.19	0.11	1.00	65.5	3.99	1.59
.046	5.56	4.65	4.33	3.99	3.70	3.46	3.20	2.67	2.30	1.97	1.71	1.39	1.14	0.82	0.64	0.30	0.20	0.12	1.00	66.7	4.04	1.58
.048	5.64	4.71	4.38	4.04	3.75	3.50	3.24	2.70	2.33	2.00	1.74	1.42	1.16	0.84	0.66	0.31	0.20	0.12	1.00	67.9	4.10	1.58
.050	5.71	4.77	4.44	4.08	3.80	3.55	3.28	2.74	2.37	2.04	1.77	1.44	1.18	0.86	0.67	0.32	0.21	0.12	1.00	69.1	4.15	1.57
.052	5.79	4.82	4.49	4.13	3.84	3.59	3.32	2.78	2.35	2.07	1.80	1.46	1.20	0.88	0.69	0.33	0.21	0.13	1.00	70.3	4.21	1.57
.054	5.86	4.88	4.55	4.18	3.89	3.63	3.36	2.81	2.39	2.10	1.83	1.49	1.23	0.90	0.70	0.33	0.22	0.13	1.00	71.5	4.27	1.56
.056	5.94	4.94	4.60	4.23	3.93	3.68	3.40	2.85	2.42	2.09	1.86	1.51	1.25	0.91	0.72	0.34	0.22	0.13	1.00	72.7	4.32	1.56
.058	6.02	5.00	4.65	4.27	3.98	3.72	3.45	2.88	2.45	2.12	1.89	1.53	1.27	0.93	0.73	0.35	0.23	0.14	1.00	73.9	4.38	1.55
.060	6.09	5.06	4.71	4.32	4.03	3.77	3.49	2.92	2.48	2.15	1.92	1.55	1.29	0.95	0.74	0.36	0.23	0.14	1.00	75.1	4.44	1.55
.062	6.17	5.12	4.76	4.37	4.07	3.81	3.53	2.95	2.52	2.18	1.95	1.57	1.31	0.96	0.76	0.36	0.24	0.14	1.00	76.2	4.49	1.54
.064	6.25	5.18	4.82	4.42	4.12	3.85	3.57	2.99	2.55	2.21	1.98	1.60	1.33	0.98	0.77	0.37	0.24	0.14	1.00	77.4	4.55	1.54
.066	6.32	5.24	4.87	4.46	4.17	3.90	3.61	3.02	2.58	2.24	1.97	1.63	1.52	1.13	0.90	0.43	0.28	0.17	1.00	78.6	4.60	1.53
.068	6.40	5.30	4.92	4.51	4.21	3.94	3.65	3.05	2.62	2.27	2.00	1.61	1.35	1.00	0.79	0.38	0.25	0.15	1.01	79.8	4.66	1.53
.070	6.47	5.36	4.98	4.56	4.26	3.99	3.69	3.09	2.65	2.30	2.02	1.63	1.37	1.02	0.81	0.39	0.26	0.15	1.02	81.0	4.72	1.52
.072	6.55	5.42	5.03	4.60	4.31	4.03	3.74	3.12	2.68	2.33	2.05	1.65	1.38	1.03	0.82	0.40	0.26	0.15	1.02	82.2	4.77	1.52
.074	6.63	5.47	5.08	4.65	4.35	4.08	3.78	3.16	2.71	2.36	2.08	1.67	1.40	1.04	0.83	0.40	0.27	0.16	1.03	83.4	4.83	1.51
.076	6.70	5.53	5.14	4.70	4.40	4.12	3.82	3.19	2.75	2.39	2.10	1.69	1.42	1.06	0.84	0.41	0.27	0.16	1.04	84.6	4.89	1.50
.078	6.78	5.59	5.19	4.74	4.45	4.16	3.86	3.23	2.78	2.42	2.13	1.72	1.44	1.08	0.86	0.42	0.27	0.16	1.05	85.8	4.94	1.50
.080	6.85	5.65	5.25	4.79	4.49	4.21	3.90	3.26	2.81	2.45	2.16	1.74	1.46	1.09	0.87	0.42	0.28	0.17	1.05	87.0	5.00	1.49

p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6																		Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO $\delta e/D$																					
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00				
.010	4.17	3.61	3.38	3.16	2.94	2.74	2.55	2.12	1.74	1.46	1.18	0.84	0.61	0.40	0.29	0.12	0.07	0.04	1.00	49.9	3.38	1.98
.012	4.25	3.68	3.44	3.22	3.00	2.80	2.61	2.17	1.81	1.53	1.28	0.92	0.69	0.44	0.33	0.14	0.09	0.05	1.00	52.0	3.44	1.99
.014	4.33	3.74	3.50	3.28	3.05	2.85	2.66	2.23	1.87	1.59	1.36	0.98	0.74	0.48	0.36	0.15	0.10	0.06	1.00	54.1	3.50	2.00
.016	4.41	3.81	3.56	3.34	3.11	2.90	2.72	2.28	1.94	1.64	1.38	1.04	0.79	0.53	0.39	0.17	0.11	0.06	1.00	56.2	3.56	2.01
.018	4.49	3.88	3.62	3.40	3.17	2.96	2.77	2.33	1.99	1.68	1.44	1.09	0.85	0.57	0.42	0.18	0.12	0.07	1.00	58.4	3.62	2.02
.020	4.57	3.94	3.68	3.46	3.22	3.01	2.83	2.37	2.05	1.74	1.50	1.13	0.90	0.61	0.46	0.20	0.13	0.07	1.00	60.5	3.68	2.02
.022	4.65	4.01	3.74	3.52	3.28	3.06	2.88	2.42	2.11	1.80	1.58	1.18	0.95	0.65	0.49	0.21	0.14	0.08	1.00	62.6	3.74	2.03
.024	4.72	4.08	3.81	3.58	3.34	3.12	2.94	2.46	2.16	1.85	1.62	1.23	0.98	0.68	0.51	0.23	0.14	0.08	1.00	64.7	3.80	2.04
.026	4.80	4.14	3.87	3.64	3.39	3.17	2.99	2.51	2.21	1.91	1.65	1.29	1.02	0.72	0.54	0.24	0.15	0.09	1.00	66.8	3.87	2.05
.028	4.88	4.21	3.93	3.70	3.45	3.22	3.04	2.56	2.26	1.96	1.68	1.33	1.06	0.75	0.57	0.25	0.16	0.09	1.00	69.0	3.93	2.06
.030	4.96	4.28	3.99	3.76	3.51	3.27	3.09	2.62	2.30	2.01	1.74	1.38	1.11	0.78	0.60	0.27	0.17	0.10	1.00	71.1	3.99	2.07
.032	5.04	4.34	4.05	3.81	3.56	3.32	3.15	2.67	2.35	2.06	1.79	1.42	1.13	0.80	0.62	0.28	0.18	0.10	1.00	73.2	4.05	2.08
.034	5.12	4.41	4.11	3.87	3.62	3.38	3.20	2.72	2.39	2.05	1.84	1.46	1.17	0.83	0.64	0.29	0.19	0.11	1.00	75.3	4.11	2.09
.036	5.20	4.48	4.17	3.93	3.68	3.43	3.25	2.77	2.44	2.10	1.89	1.50	1.21	0.86	0.66	0.30	0.19	0.11	1.00	77.4	4.17	2.09
.038	5.28	4.54	4.24	3.99	3.73	3.48	3.30	2.83	2.48	2.14	1.89	1.53	1.25	0.89	0.69	0.31	0.20	0.12	1.01	79.6	4.23	2.10
.040	5.35	4.61	4.30	4.05	3.79	3.53	3.35	2.88	2.52	2.18	1.93	1.57	1.29	0.92	0.71	0.33	0.21	0.12	1.02	81.7	4.29	2.11
.042	5.43	4.68	4.36	4.11	3.85	3.58	3.40	2.93	2.56	2.22	1.97	1.60	1.31	0.95	0.73	0.34	0.22	0.13	1.03	83.8	4.35	2.12
.044	5.51	4.74	4.42	4.17	3.90	3.63	3.45	2.98	2.60	2.26	2.01	1.63	1.34	0.97	0.76	0.35	0.23	0.13	1.05	85.9	4.41	2.13
.046	5.59	4.81	4.48	4.23	3.96	3.68	3.50	3.03	2.64	2.30	2.05	1.65	1.38	1.00	0.78	0.36	0.23	0.14	1.06	88.0	4.47	2.14
.048	5.67	4.88	4.54	4.29	4.01	3.73	3.55	3.08	2.68	2.35	2.09	1.70	1.41	1.03	0.80	0.37	0.24	0.14	1.07	90.2	4.53	2.15
.050	5.75	4.94	4.60	4.35	4.07	3.78	3.60	3.13	2.71	2.39	2.12	1.74	1.44	1.05	0.82	0.38	0.25	0.15	1.08	92.3	4.59	2.16
.052	5.83	5.01	4.67	4.40	4.13	3.83	3.65	3.18	2.75	2.43	2.16	1.75	1.47	1.08	0.84	0.39	0.26	0.15	1.10	94.4	4.65	2.17
.054	5.91	5.08	4.73	4.46	4.18	3.88	3.70	3.23	2.78	2.47	2.20	1.78	1.50	1.11	0.86	0.41	0.26	0.15	1.11	96.5	4.71	2.17
.056	5.99	5.14	4.79	4.52	4.24	3.94	3.75	3.28	2.82	2.51	2.24	1.82	1.53	1.13	0.88	0.41	0.27	0.16	1.12	98.6	4.77	2.18
.058	6.06	5.21	4.85	4.58	4.30	3.99	3.80	3.24	2.85	2.55	2.27	1.85	1.57	1.15	0.90	0.43	0.28	0.16	1.13	100.8	4.84	2.19
.060	6.14	5.28	4.91	4.64	4.35	4.04	3.85	3.29	2.89	2.58	2.31	1.89	1.60	1.17	0.93	0.44	0.28	0.17	1.14	102.9	4.90	2.20
.062	6.22	5.34	4.97	4.70	4.41	4.10	3.90	3.34	2.92	2.62	2.35	1.92	1.62	1.20	0.94	0.45	0.29	0.17	1.16	105.0	4.96	2.21
.064	6.30	5.41	5.04	4.76	4.46	4.15	3.95	3.38	2.96	2.66	2.39	1.95	1.63	1.22	0.96	0.46	0.30	0.18	1.17	107.1	5.02	2.22
.066	6.38	5.48	5.10	4.82	4.52	4.20	4.00	3.43	2.99	2.70	2.43	1.98	1.67	1.25	0.98	0.47	0.31	0.18	1.18	109.2	5.08	2.23
.068	6.46	5.54	5.16	4.88	4.58	4.26	4.05	3.47	3.04	2.74	2.46	2.02	1.68	1.27	1.00	0.48	0.31	0.18	1.19	111.4	5.14	2.24
.070	6.54	5.61	5.22	4.93	4.63	4.31	4.10	3.52	3.09	2.77	2.50	2.05	1.71	1.29	1.02	0.49	0.32	0.19	1.20	113.5	5.20	2.24
.072	6.62	5.68	5.28	4.99	4.69	4.36	4.15	3.56	3.13	2.81	2.54	2.08	1.74	1.31	1.04	0.50	0.33	0.19	1.21	115.6	5.26	2.25
.074	6.70	5.74	5.34	5.05	4.75	4.42	4.20	3.61	3.18	2.85	2.54	2.11	1.77	1.34	1.06	0.51	0.33	0.20	1.22	117.7	5.32	2.26
.076	6.77	5.81	5.41	5.11	4.80	4.47	4.25	3.65	3.23	2.88	2.57	2.14	1.80	1.36	1.08	0.52	0.34	0.20	1.24	119.9	5.38	2.27
.078	6.85	5.88	5.47	5.17	4.86	4.52	4.30	3.70	3.27	2.92	2.61	2.17	1.83	1.38	1.10	0.53	0.35	0.20	1.25	122.0	5.44	2.28
.080	6.93	5.94	5.53	5.23	4.91	4.58	4.34	3.74	3.32	2.96	2.64	2.21	1.86	1.40	1.11	0.54	0.35	0.21	1.26	124.1	5.50	2.29

L/D_e	VALUES OF MOMENT MULTIPLIERS δ — VALUES OF ULTIMATE STRESS P_u/A_g IN KSI: 0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03
3.0	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06
4.0	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
5.0	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.08	1.10	1.11	1.13	1.15	1.16	1.18	1.20
6.0	1.01	1.01	1.02	1.03	1.04	1.05	1.05	1.06	1.07	1.08	1.09	1.10	1.10	1.11	1.12	1.15	1.17	1.20	1.22	1.25	1.28	1.31
7.0	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.11	1.13	1.14	1.15	1.16	1.18	1.21	1.25	1.30	1.35	1.38	1.42	1.48
8.0	1.01	1.03	1.04	1.05	1.07	1.08	1.10	1.12	1.13	1.15	1.17	1.18	1.20	1.22	1.24	1.29	1.35	1.41	1.48	1.55	1.64	1.73
9.0	1.02	1.03	1.05	1.07	1.09	1.11	1.13	1.15	1.17	1.20	1.22	1.25	1.27	1.30	1.33	1.40	1.49	1.59	1.70	1.82	1.97	2.14
10.0	1.02	1.04	1.06	1.09	1.11	1.14	1.17	1.19	1.22	1.25	1.29	1.32	1.36	1.40	1.44	1.55	1.68	1.84	2.03	2.26	2.55	2.93
11.0	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.32	1.37	1.42	1.47	1.52	1.58	1.75	1.96	2.23	2.58	3.07	3.78	4.92
12.0	1.03	1.06	1.10	1.13	1.17	1.21	1.26	1.30	1.36	1.41	1.47	1.54	1.61	1.69	1.78	2.04	2.40	2.91	3.70	5.06	8.03	
13.0	1.04	1.07	1.11	1.16	1.21	1.26	1.32	1.38	1.45	1.52	1.60	1.70	1.80	1.92	2.06	2.50	3.17	4.36	6.95			
14.0	1.04	1.09	1.14	1.19	1.25	1.31	1.39	1.47	1.56	1.66	1.78	1.91	2.07	2.25	2.47	3.28	4.86	9.40				
15.0	1.05	1.10	1.16	1.22	1.30	1.38	1.47	1.57	1.70	1.84	2.01	2.21	2.46	2.76	3.16	4.95						
16.0	1.05	1.12	1.18	1.26	1.35	1.45	1.57	1.71	1.88	2.08	2.33	2.65	3.07	3.65	4.51							
17.0	1.06	1.13	1.21	1.31	1.41	1.54	1.69	1.88	2.11	2.41	2.81	3.36	4.19	5.55	8.23							
18.0	1.07	1.15	1.25	1.36	1.49	1.65	1.85	2.11	2.44	2.91	3.60	4.71	6.83									

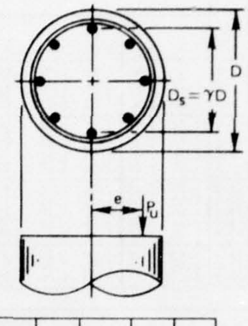
VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .75$

p_g Steel Ratio	VALUES OF ECCENTRICITY RATIO $\delta e/D$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
.010	4.19	3.64	3.42	3.21	3.01	2.81	2.64	2.21	1.85	1.55	1.28	0.90	0.67	0.43	0.31	0.12	0.08	0.05	1.00	55.8	3.71	2.25
.012	4.27	3.71	3.49	3.28	3.08	2.87	2.71	2.28	1.93	1.63	1.38	0.99	0.75	0.49	0.35	0.14	0.09	0.05	1.00	59.2	3.77	2.27
.014	4.35	3.79	3.56	3.35	3.15	2.94	2.77	2.35	2.01	1.69	1.47	1.08	0.83	0.54	0.40	0.16	0.10	0.06	1.00	62.5	3.83	2.28
.016	4.43	3.86	3.63	3.42	3.21	3.00	2.83	2.43	2.08	1.77	1.54	1.13	0.88	0.58	0.43	0.18	0.12	0.07	1.00	65.8	3.90	2.30
.018	4.51	3.93	3.70	3.48	3.28	3.07	2.90	2.50	2.14	1.84	1.60	1.22	0.94	0.63	0.47	0.20	0.13	0.07	1.00	69.1	3.96	2.32
.020	4.59	4.00	3.77	3.55	3.35	3.14	2.95	2.56	2.20	1.91	1.65	1.26	1.00	0.68	0.51	0.22	0.14	0.08	1.00	72.4	4.02	2.33
.022	4.67	4.08	3.84	3.61	3.41	3.20	3.01	2.63	2.26	1.98	1.70	1.32	1.04	0.73	0.55	0.24	0.15	0.09	1.00	75.7	4.09	2.35
.024	4.75	4.15	3.91	3.68	3.48	3.27	3.07	2.69	2.32	2.04	1.77	1.38	1.09	0.77	0.58	0.25	0.16	0.09	1.00	79.0	4.15	2.37
.026	4.83	4.22	3.98	3.74	3.54	3.33	3.13	2.76	2.37	2.10	1.84	1.44	1.15	0.81	0.61	0.27	0.17	0.10	1.02	82.3	4.21	2.38
.028	4.92	4.29	4.05	3.81	3.61	3.40	3.18	2.82	2.42	2.15	1.90	1.49	1.20	0.85	0.64	0.28	0.18	0.11	1.04	85.7	4.28	2.40
.030	5.00	4.36	4.12	3.87	3.67	3.46	3.24	2.88	2.49	2.21	1.96	1.54	1.25	0.89	0.68	0.30	0.19	0.11	1.06	89.0	4.34	2.41
.032	5.08	4.43	4.19	3.94	3.74	3.53	3.31	2.94	2.55	2.26	2.02	1.61	1.30	0.93	0.71	0.32	0.20	0.12	1.08	92.3	4.40	2.43
.034	5.16	4.51	4.26	4.00	3.80	3.59	3.37	2.99	2.62	2.31	2.07	1.64	1.35	0.95	0.74	0.33	0.21	0.12	1.10	95.6	4.47	2.45
.036	5.24	4.58	4.33	4.06	3.86	3.65	3.43	3.05	2.68	2.36	2.12	1.67	1.38	0.99	0.77	0.35	0.22	0.13	1.12	98.9	4.53	2.46
.038	5.32	4.65	4.40	4.13	3.93	3.72	3.49	3.11	2.74	2.40	2.17	1.73	1.42	1.03	0.80	0.36	0.23	0.14	1.14	102.2	4.59	2.48
.040	5.41	4.72	4.47	4.20	3.99	3.78	3.56	3.16	2.80	2.45	2.22	1.79	1.46	1.06	0.83	0.38	0.24	0.14	1.16	105.5	4.65	2.49
.042	5.49	4.79	4.54	4.26	4.05	3.84	3.62	3.21	2.79	2.49	2.27	1.84	1.52	1.09	0.85	0.39	0.25	0.15	1.18	108.9	4.72	2.51
.044	5.57	4.86	4.61	4.33	4.11	3.90	3.68	3.27	2.84	2.54	2.31	1.85	1.55	1.13	0.88	0.40	0.26	0.15	1.20	112.2	4.78	2.53
.046	5.65	4.93	4.67	4.40	4.18	3.96	3.74	3.32	2.89	2.59	2.36	1.90	1.59	1.17	0.90	0.42	0.27	0.16	1.21	115.5	4.84	2.54
.048	5.73	5.00	4.74	4.46	4.24	4.03	3.80	3.37	2.94	2.65	2.40	1.94	1.63	1.20	0.93	0.43	0.28	0.16	1.23	118.8	4.91	2.56
.050	5.81	5.07	4.81	4.53	4.30	4.09	3.86	3.42	2.99	2.70	2.44	1.98	1.65	1.22	0.96	0.45	0.29	0.17	1.25	122.1	4.97	2.58
.052	5.89	5.14	4.88	4.60	4.36	4.15	3.92	3.48	3.05	2.76	2.48	2.03	1.71	1.26	0.99	0.46	0.30	0.17	1.26	125.4	5.03	2.59
.054	5.97	5.22	4.95	4.66	4.42	4.21	3.98	3.53	3.10	2.82	2.52	2.07	1.73	1.29	1.01	0.47	0.31	0.18	1.28	128.7	5.10	2.61
.056	6.05	5.29	5.02	4.73	4.48	4.27	4.04	3.58	3.15	2.81	2.56	2.11	1.76	1.32	1.04	0.49	0.32	0.19	1.30	132.0	5.16	2.62
.058	6.13	5.36	5.09	4.80	4.55	4.33	4.10	3.63	3.20	2.86	2.60	2.15	1.80	1.35	1.06	0.50	0.33	0.19	1.31	135.4	5.22	2.64
.060	6.21	5.43	5.16	4.86	4.61	4.39	4.16	3.68	3.25	2.90	2.64	2.19	1.84	1.39	1.09	0.52	0.33	0.20	1.33	138.7	5.29	2.66
.062	6.30	5.50	5.22	4.93	4.67	4.45	4.22	3.73	3.30	2.95	2.67	2.23	1.88	1.42	1.11	0.53	0.34	0.20	1.34	142.0	5.35	2.67
.064	6.38	5.57	5.29	4.99	4.73	4.51	4.28	3.78	3.34	3.00	2.71	2.27	1.91	1.45	1.14	0.54	0.35	0.21	1.36	145.3	5.41	2.69
.066	6.46	5.64	5.36	5.06	4.79	4.57	4.34	3.82	3.39	3.04	2.76	2.31	1.95	1.47	1.16	0.55	0.36	0.21	1.38	148.6	5.48	2.70
.068	6.54	5.71	5.43	5.13	4.85	4.63	4.40	3.87	3.44	3.09	2.81	2.35	1.99	1.50	1.19	0.57	0.37	0.22	1.39	151.9	5.54	2.72
.070	6.62	5.78	5.50	5.19	4.91	4.69	4.46	3.92	3.49	3.13	2.87	2.39	2.02	1.53	1.21	0.58	0.38	0.22	1.41	155.2	5.60	2.74
.072	6.71	5.85	5.57	5.26	4.97	4.75	4.52	3.97	3.54	3.18	2.92	2.43	2.06	1.56	1.23	0.59	0.39	0.23	1.42	158.6	5.67	2.75
.074	6.79	5.92	5.63	5.32	5.03	4.81	4.58	4.02	3.59	3.22	2.92	2.46	2.10	1.59	1.26	0.60	0.39	0.23	1.44	161.9	5.73	2.77
.076	6.87	5.99	5.70	5.39	5.09	4.87	4.64	4.06	3.64	3.27	2.96	2.50	2.13	1.60	1.28	0.62	0.40	0.24	1.45	165.2	5.79	2.78
.078	6.95	6.06	5.77	5.46	5.15	4.93	4.70	4.11	3.69	3.32	3.00	2.54	2.17	1.64	1.30	0.63	0.41	0.24	1.46	168.5	5.86	2.80
.080	7.03	6.13	5.84	5.52	5.21	4.99	4.75	4.16	3.73	3.36	3.04	2.57	2.20	1.65	1.33	0.64	0.42	0.25	1.48	171.8	5.92	2.82

VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .9$

p_g Steel Ratio	VALUES OF ECCENTRICITY RATIO $\delta e/D$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
.010	4.20	3.68	3.47	3.27	3.08	2.89	2.71	2.31	1.95	1.63	1.38	0.97	0.73	0.46	0.33	0.13	0.08	0.05	1.00	63.1	4.00	2.51
.012	4.29	3.76	3.55	3.34	3.16	2.97	2.79	2.39	2.04	1.72	1.48	1.09	0.81	0.53	0.38	0.16	0.10	0.06	1.00	67.9	4.07	2.53
.014	4.37	3.83	3.63	3.41	3.23	3.05	2.86	2.47	2.13	1.81	1.57	1.15	0.90	0.59	0.43	0.18	0.11	0.06	1.00	72.7	4.13	2.55
.016	4.46	3.91	3.71	3.49	3.31	3.13	2.94	2.55	2.20	1.91	1.64	1.25	0.97	0.64	0.48	0.20	0.13	0.07	1.00	77.4	4.20	2.57
.018	4.54	3.99	3.78	3.57	3.38	3.20	3.01	2.63	2.27	1.99	1.71	1.30	1.04	0.70	0.52	0.22	0.14	0.08	1.02	82.2	4.26	2.60
.020	4.63	4.06	3.86	3.64	3.45	3.27	3.09	2.70	2.35	2.06	1.79	1.38	1.09	0.75	0.56	0.24	0.15	0.09	1.05	87.0	4.33	2.62
.022	4.72	4.14	3.93	3.72	3.52	3.35	3.16	2.77	2.42	2.14	1.87	1.45	1.15	0.81	0.60	0.26	0.17	0.10	1.08	91.8	4.39	2.64
.024	4.80	4.21	4.01	3.79	3.59	3.42	3.24	2.84	2.49	2.20	1.95	1.52	1.22	0.85	0.64	0.28	0.18	0.10	1.11	96.5	4.46	2.66
.026	4.89	4.29	4.08	3.87	3.66	3.49	3.31	2.90	2.56	2.26	2.02	1.60	1.28	0.90	0.68	0.30	0.19	0.11	1.14	101.3	4.52	2.68
.028	4.97	4.37	4.16	3.94	3.73	3.56	3.38	2.97	2.63	2.32	2.08	1.64	1.34	0.95	0.72	0.32	0.20	0.12	1.16	106.1	4.59	2.70
.030	5.06	4.45	4.23	4.02	3.79	3.63	3.45	3.03	2.70	2.38	2.15	1.70	1.39	0.99	0.76	0.34	0.21	0.12	1.19	110.8	4.65	2.72
.032	5.14	4.53	4.31	4.09	3.86	3.69	3.52	3.09	2.76	2.45	2.20	1.77	1.45	1.03	0.80	0.35	0.23	0.13	1.21	115.6	4.72	2.74
.034	5.23	4.60	4.38	4.16	3.94	3.76	3.59	3.15	2.83	2.51	2.26	1.83	1.50	1.07	0.83	0.37	0.24	0.14	1.24	120.4	4.78	2.76
.036	5.31	4.68	4.45	4.24	4.01	3.82	3.65	3.20	2.89	2.57	2.31	1.90	1.55	1.12	0.87	0.39	0.25	0.15	1.26	125.2	4.85	2.78
.038	5.40	4.76	4.53	4.31	4.08	3.89	3.72	3.27	2.95	2.63	2.36	1.92	1.61	1.17	0.90	0.41	0.26	0.15	1.29	129.9	4.91	2.81
.040	5.48	4.84	4.60	4.38	4.15	3.95	3.79	3.33	3.01	2.69	2.41	1.97	1.64	1.20	0.93	0.43	0.27	0.16	1.31	134.7	4.98	2.83
.042	5.56	4.92	4.67	4.45	4.22	4.02	3.85	3.40	3.07	2.75	2.47	2.02	1.69	1.24	0.96	0.44	0.28	0.17	1.33	139.5	5.04	2.85
.044	5.65	4.99	4.74	4.52	4.29	4.08	3.91	3.47	3.12	2.81	2.52	2.08	1.75	1.28	1.00	0.46	0.30	0.17	1.36	144.2	5.11	2.87
.046	5.73	5.07	4.81	4.60	4.36	4.14	3.98	3.53	3.18	2.87	2.58	2.13	1.78	1.32	1.03	0.48	0.31	0.18	1.38	149.0	5.17	2.89
.048	5.82	5.15	4.89	4.67	4.44	4.21	4.04	3.60	3.23	2.93	2.64	2.18	1.82	1.36	1.06	0.49	0.32	0.19	1.40	153.8	5.24	2.91
.050	5.90	5.22	4.96	4.74	4.51	4.27	4.10	3.66	3.29	2.99	2.69	2.23	1.87	1.40	1.09	0.51	0.33	0.19	1.42	158.6	5.30	2.93
.052	5.98	5.30	5.03	4.81	4.58	4.33	4.17	3.73	3.34	3.04	2.75	2.27	1.92	1.43	1.13	0.53	0.34	0.20	1.44	163.3	5.37	2.95
.054	6.07	5.38	5.10	4.88	4.65	4.40	4.23	3.79	3.39	3.10	2.80	2.35	1.96	1.47	1.15	0.54	0.35	0.21	1.46	168.1	5.43	2.97
.056	6.15	5.45	5.17	4.95	4.72	4.47	4.29	3.85	3.44	3.15	2.86	2.40	2.01	1.51	1.18	0.56	0.36	0.21	1.48	172.9	5.50	2.99
.058	6.23	5.53	5.24	5.02	4.78	4.54	4.35	3.92	3.49	3.21	2.91	2.44	2.05	1.54	1.22	0.57	0.37	0.22	1.50	177.6	5.56	3.01
.060	6.32	5.61	5.31	5.09	4.85	4.60	4.41	3.98	3.54	3.26	2.96	2.47	2.09	1.58	1.25	0.59	0.38	0.22	1.52	182.4	5.63	3.04
.062	6.40	5.68	5.39	5.16	4.92	4.67	4.47	4.04	3.59	3.31	3.02	2.51	2.14	1.61	1.28	0.61	0.39	0.23	1.54	187.2	5.69	3.06
.064	6.48	5.76	5.46	5.23	4.99	4.74	4.53	4.10	3.64	3.36	3.07	2.55	2.18	1.65	1.31	0.62	0.40	0.24	1.56	192.0	5.76	3.08
.066	6.57	5.83	5.54	5.30	5.06	4.81	4.59	4.16	3.69	3.41	3.12	2.59	2.22	1.67	1.34	0.64	0.41	0.24	1.58	196.7	5.82	3.10
.068	6.65	5.91	5.61	5.37	5.13	4.88	4.65	4.22	3.75	3.46	3.12	2.64	2.26	1.71	1.36	0.65	0.43	0.25	1.60	201.5	5.89	3.12
.070	6.73	5.99	5.69	5.44	5.20	4.94	4.71	4.28	3.81	3.51	3.17	2.69	2.30	1.74	1.39	0.67	0.44	0.26	1.62	206.3	5.95	3.14
.072	6.81	6.06	5.76	5.50	5.26	5.01	4.77	4.34	3.87	3.56	3.21	2.74	2.34	1.78	1.42	0.68	0.45	0.26	1.64	211.0	6.02	3.16
.074	6.90	6.14	5.83	5.57	5.33	5.08	4.83	4.40	3.93	3.61	3.26	2.78	2.38	1.81	1.46	0.70	0.46	0.27	1.66	215.8	6.08	3.18
.076	6.98	6.21	5.91	5.64	5.40	5.15	4.89	4.46	3.99	3.66	3.31	2.83	2.42	1.85	1.48	0.71	0.47	0.27	1.68	220.6	6.15	3.20
.078	7.06	6.29	5.98	5.71	5.47	5.21	4.95	4.52	4.05	3.70	3.36	2.88	2.46	1.88	1.51	0.73	0.48	0.28	1.69	225.4	6.21	3.22
.080	7.14	6.36	6.06	5.78	5.54	5.28	5.01	4.58	4.11	3.75	3.40	2.93	2.50	1.92	1.54	0.74	0.49	0.29	1.71	230.1	6.28	3.24

Table 6.7A.3 Values of ultimate axial stress, P_u/A_g, for circular column, f'_c = 5 ksi, f_{dy} = 52 ksi, γ = 0.45, 0.60, 0.75, 0.90



VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .45

p_g Steel Ratio	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO $\delta e/D$																					
.010	5.12	4.40	4.11	3.82	3.54	3.26	3.01	2.44	1.94	1.60	1.27	0.90	0.66	0.42	0.30	0.13	0.08	0.05	1.00	55.1	3.47	1.93
.012	5.19	4.46	4.16	3.87	3.58	3.30	3.05	2.48	1.99	1.66	1.35	0.95	0.72	0.46	0.34	0.14	0.09	0.05	1.00	56.2	3.53	1.93
.014	5.27	4.52	4.22	3.92	3.63	3.34	3.09	2.52	2.05	1.71	1.43	1.01	0.77	0.50	0.37	0.16	0.10	0.06	1.00	57.4	3.58	1.92
.016	5.35	4.58	4.27	3.97	3.67	3.38	3.13	2.57	2.10	1.76	1.44	1.06	0.81	0.54	0.40	0.17	0.11	0.06	1.00	58.6	3.64	1.92
.018	5.42	4.64	4.32	4.01	3.71	3.42	3.17	2.61	2.15	1.80	1.49	1.11	0.86	0.57	0.43	0.19	0.12	0.07	1.00	59.8	3.69	1.91
.020	5.50	4.70	4.38	4.06	3.75	3.46	3.21	2.64	2.20	1.84	1.54	1.15	0.90	0.61	0.46	0.20	0.13	0.07	1.00	61.0	3.75	1.91
.022	5.58	4.76	4.43	4.11	3.80	3.51	3.25	2.68	2.25	1.87	1.59	1.18	0.94	0.64	0.48	0.21	0.14	0.08	1.00	62.2	3.80	1.90
.024	5.65	4.82	4.48	4.16	3.84	3.55	3.29	2.72	2.22	1.90	1.63	1.22	0.97	0.67	0.51	0.22	0.14	0.08	1.00	63.4	3.86	1.90
.026	5.73	4.89	4.53	4.21	3.88	3.59	3.33	2.76	2.26	1.92	1.67	1.26	1.00	0.70	0.53	0.24	0.15	0.09	1.00	64.6	3.92	1.89
.028	5.81	4.95	4.59	4.26	3.92	3.63	3.37	2.79	2.30	1.94	1.70	1.31	1.02	0.71	0.54	0.25	0.16	0.09	1.00	65.8	3.97	1.88
.030	5.88	5.01	4.64	4.31	3.96	3.67	3.41	2.83	2.33	2.00	1.74	1.32	1.06	0.74	0.57	0.26	0.17	0.10	1.00	67.0	4.03	1.88
.032	5.96	5.07	4.69	4.35	4.01	3.71	3.45	2.87	2.37	2.05	1.77	1.36	1.08	0.76	0.59	0.27	0.17	0.10	1.00	68.2	4.08	1.87
.034	6.04	5.12	4.74	4.40	4.05	3.76	3.49	2.90	2.41	2.04	1.80	1.39	1.11	0.78	0.60	0.28	0.18	0.10	1.00	69.4	4.14	1.87
.036	6.11	5.18	4.79	4.45	4.09	3.80	3.53	2.94	2.44	2.07	1.83	1.43	1.15	0.80	0.62	0.29	0.18	0.11	1.00	70.6	4.19	1.86
.038	6.19	5.24	4.84	4.50	4.13	3.84	3.57	2.97	2.48	2.11	1.87	1.45	1.16	0.84	0.64	0.29	0.19	0.11	1.00	71.8	4.25	1.86
.040	6.26	5.30	4.89	4.55	4.17	3.88	3.61	3.01	2.52	2.14	1.89	1.48	1.19	0.85	0.66	0.30	0.20	0.12	1.00	72.9	4.30	1.85
.042	6.34	5.36	4.95	4.59	4.21	3.93	3.65	3.04	2.55	2.17	1.90	1.51	1.23	0.88	0.67	0.31	0.20	0.12	1.00	74.1	4.36	1.84
.044	6.41	5.42	5.00	4.64	4.25	3.97	3.69	3.07	2.59	2.21	1.92	1.54	1.24	0.89	0.69	0.32	0.21	0.12	1.00	75.3	4.41	1.84
.046	6.49	5.48	5.05	4.69	4.30	4.01	3.73	3.11	2.62	2.24	1.96	1.57	1.27	0.92	0.71	0.33	0.21	0.13	1.00	76.5	4.47	1.83
.048	6.56	5.54	5.11	4.74	4.34	4.05	3.77	3.14	2.66	2.27	2.02	1.59	1.29	0.93	0.72	0.34	0.22	0.13	1.00	77.7	4.53	1.83
.050	6.64	5.60	5.16	4.78	4.38	4.10	3.81	3.18	2.69	2.31	2.00	1.61	1.32	0.95	0.74	0.35	0.23	0.13	1.00	78.9	4.58	1.82
.052	6.72	5.65	5.21	4.83	4.42	4.14	3.85	3.21	2.73	2.34	2.03	1.64	1.34	0.97	0.76	0.35	0.23	0.14	1.00	80.1	4.64	1.82
.054	6.79	5.71	5.27	4.88	4.46	4.18	3.89	3.24	2.76	2.37	2.06	1.66	1.37	0.99	0.77	0.36	0.24	0.14	1.00	81.3	4.69	1.81
.056	6.87	5.77	5.32	4.93	4.50	4.22	3.93	3.28	2.80	2.41	2.08	1.69	1.39	1.01	0.79	0.37	0.24	0.14	1.00	82.5	4.75	1.81
.058	6.94	5.83	5.37	4.97	4.55	4.27	3.97	3.31	2.83	2.44	2.11	1.71	1.41	1.02	0.80	0.38	0.25	0.15	1.00	83.7	4.80	1.80
.060	7.02	5.89	5.43	5.02	4.59	4.31	4.01	3.34	2.81	2.43	2.14	1.73	1.43	1.04	0.81	0.38	0.25	0.15	1.00	84.9	4.86	1.79
.062	7.09	5.94	5.48	5.07	4.64	4.35	4.05	3.38	2.84	2.45	2.18	1.76	1.45	1.06	0.83	0.39	0.26	0.15	1.00	86.1	4.91	1.79
.064	7.17	6.00	5.53	5.12	4.68	4.39	4.09	3.41	2.87	2.48	2.21	1.78	1.47	1.08	0.84	0.40	0.26	0.15	1.00	87.3	4.97	1.78
.066	7.24	6.06	5.59	5.16	4.73	4.44	4.13	3.44	2.91	2.51	2.24	1.80	1.49	1.09	0.86	0.41	0.27	0.16	1.00	88.5	5.02	1.78
.068	7.32	6.12	5.64	5.21	4.77	4.48	4.17	3.47	2.94	2.54	2.27	1.82	1.51	1.11	0.87	0.41	0.27	0.16	1.00	89.6	5.08	1.77
.070	7.39	6.17	5.69	5.26	4.82	4.52	4.21	3.51	2.97	2.57	2.30	1.84	1.53	1.13	0.88	0.42	0.28	0.16	1.00	90.8	5.13	1.77
.072	7.47	6.23	5.75	5.31	4.86	4.57	4.25	3.54	3.00	2.60	2.28	1.87	1.55	1.14	0.90	0.43	0.28	0.17	1.00	92.0	5.19	1.76
.074	7.54	6.29	5.80	5.35	4.91	4.61	4.29	3.57	3.03	2.63	2.31	1.87	1.57	1.16	0.91	0.44	0.29	0.17	1.00	93.2	5.25	1.76
.076	7.62	6.34	5.85	5.40	4.95	4.65	4.33	3.60	3.07	2.66	2.33	1.89	1.57	1.17	0.92	0.44	0.29	0.17	1.00	94.4	5.30	1.75
.078	7.69	6.40	5.91	5.45	5.00	4.69	4.37	3.64	3.10	2.69	2.36	1.89	1.59	1.18	0.94	0.45	0.29	0.17	1.00	95.6	5.36	1.74
.080	7.77	6.46	5.96	5.49	5.04	4.74	4.41	3.67	3.13	2.72	2.39	1.92	1.60	1.19	0.95	0.46	0.30	0.18	1.00	96.8	5.41	1.74

VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6

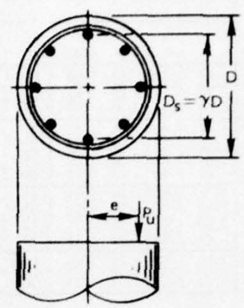
p_g Steel Ratio	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO $\delta e/D$																					
.010	5.12	4.42	4.14	3.86	3.60	3.33	3.09	2.53	2.07	1.71	1.37	0.94	0.69	0.43	0.31	0.12	0.08	0.04	1.00	59.7	3.89	2.28
.012	5.20	4.48	4.20	3.92	3.65	3.38	3.15	2.59	2.14	1.78	1.47	1.03	0.75	0.48	0.35	0.14	0.09	0.05	1.00	61.8	3.95	2.28
.014	5.28	4.55	4.26	3.97	3.71	3.43	3.20	2.64	2.21	1.84	1.55	1.11	0.81	0.52	0.39	0.16	0.10	0.06	1.00	63.9	4.01	2.29
.016	5.36	4.61	4.32	4.03	3.76	3.48	3.25	2.69	2.27	1.90	1.63	1.17	0.88	0.57	0.42	0.18	0.11	0.06	1.00	66.1	4.07	2.30
.018	5.43	4.68	4.38	4.08	3.82	3.54	3.30	2.73	2.33	1.95	1.69	1.21	0.93	0.62	0.46	0.19	0.12	0.07	1.00	68.2	4.13	2.31
.020	5.51	4.74	4.44	4.14	3.87	3.59	3.35	2.79	2.39	2.01	1.75	1.29	0.99	0.66	0.49	0.21	0.13	0.08	1.00	70.3	4.19	2.32
.022	5.59	4.81	4.51	4.20	3.93	3.64	3.40	2.84	2.44	2.07	1.80	1.32	1.04	0.70	0.52	0.22	0.14	0.08	1.00	72.4	4.25	2.33
.024	5.67	4.87	4.57	4.26	3.98	3.69	3.46	2.89	2.50	2.13	1.84	1.38	1.09	0.74	0.55	0.24	0.15	0.09	1.00	74.5	4.31	2.33
.026	5.75	4.94	4.63	4.31	4.03	3.74	3.51	2.95	2.55	2.18	1.88	1.43	1.12	0.78	0.58	0.25	0.16	0.09	1.00	76.7	4.37	2.34
.028	5.82	5.00	4.69	4.37	4.09	3.80	3.56	3.00	2.60	2.24	1.92	1.48	1.16	0.81	0.61	0.27	0.17	0.10	1.00	78.8	4.43	2.35
.030	5.90	5.07	4.75	4.43	4.14	3.85	3.61	3.05	2.64	2.29	1.96	1.53	1.21	0.85	0.64	0.28	0.18	0.10	1.00	80.9	4.49	2.36
.032	5.98	5.13	4.81	4.48	4.20	3.90	3.66	3.11	2.69	2.34	2.02	1.58	1.26	0.88	0.67	0.30	0.19	0.11	1.00	83.0	4.55	2.37
.034	6.06	5.20	4.87	4.54	4.25	3.95	3.70	3.16	2.73	2.39	2.07	1.62	1.30	0.91	0.69	0.31	0.20	0.11	1.00	85.1	4.60	2.37
.036	6.14	5.26	4.93	4.60	4.31	4.00	3.75	3.21	2.77	2.38	2.12	1.67	1.33	0.93	0.71	0.32	0.21	0.12	1.00	87.3	4.66	2.38
.038	6.22	5.33	4.99	4.65	4.36	4.06	3.80	3.26	2.82	2.42	2.17	1.71	1.37	0.97	0.74	0.33	0.21	0.12	1.00	89.4	4.72	2.39
.040	6.29	5.39	5.05	4.71	4.42	4.11	3.85	3.31	2.86	2.46	2.22	1.74	1.41	0.99	0.76	0.35	0.22	0.13	1.00	91.5	4.78	2.40
.042	6.37	5.46	5.11	4.77	4.47	4.16	3.90	3.36	2.90	2.51	2.21	1.78	1.44	1.03	0.78	0.36	0.23	0.13	1.00	93.6	4.84	2.41
.044	6.45	5.52	5.17	4.82	4.53	4.21	3.95	3.41	2.94	2.55	2.25	1.81	1.46	1.05	0.81	0.37	0.24	0.14	1.00	95.7	4.90	2.42
.046	6.53	5.59	5.23	4.88	4.58	4.26	4.00	3.46	2.97	2.59	2.29	1.86	1.52	1.08	0.83	0.38	0.25	0.14	1.00	97.9	4.96	2.42
.048	6.61	5.65	5.29	4.94	4.64	4.32	4.05	3.51	3.01	2.63	2.33	1.88	1.56	1.11	0.86	0.39	0.25	0.15	1.01	100.0	5.02	2.43
.050	6.68	5.72	5.35	5.00	4.69	4.37	4.09	3.56	3.05	2.67	2.37	1.90	1.57	1.13	0.88	0.41	0.26	0.15	1.02	102.1	5.08	2.44
.052	6.76	5.78	5.41	5.05	4.75	4.42	4.14	3.61	3.08	2.71	2.41	1.95	1.61	1.16	0.90	0.42	0.27	0.16	1.03	104.2	5.14	2.45
.054	6.84	5.85	5.47	5.11	4.80	4.47	4.19	3.65	3.12	2.75	2.44	1.99	1.64	1.19	0.93	0.43	0.28	0.16	1.04	106.3	5.20	2.46
.056	6.92	5.91	5.54	5.17	4.85	4.52	4.24	3.70	3.15	2.79	2.48	2.04	1.67	1.21	0.94	0.44	0.28	0.17	1.05	108.5	5.26	2.46
.058	7.00	5.98	5.60	5.22	4.91	4.58	4.29	3.75	3.19	2.83	2.52	2.04	1.70	1.24	0.97	0.45	0.29	0.17	1.06	110.6	5.32	2.47
.060	7.07	6.04	5.66	5.28	4.96	4.63	4.33	3.80	3.22	2.87	2.56	2.07	1.73	1.27	0.99	0.46	0.30	0.18	1.07	112.7	5.38	2.48
.062	7.15	6.11	5.72	5.34	5.02	4.68	4.38	3.85	3.26	2.91	2.60	2.10	1.77	1.29	1.01	0.47	0.31	0.18	1.08	114.8	5.44	2.49
.064	7.23	6.17	5.78	5.39	5.07	4.73	4.43	3.80	3.30	2.95	2.63	2.14	1.80	1.32	1.03	0.48	0.31	0.18	1.09	116.9	5.50	2.50
.066	7.31	6.24	5.84	5.45	5.13	4.78	4.48	3.84	3.35	2.99	2.67	2.17	1.83	1.35	1.05	0.49	0.32	0.19	1.10	119.1	5.56	2.50
.068	7.39	6.30	5.90	5.51	5.18	4.84	4.53	3.89	3.39	3.02	2.71	2.20	1.85	1.36	1.07	0.50	0.33	0.19	1.11	121.2	5.62	2.51
.070	7.46	6.37	5.96	5.57	5.24	4.89	4.57	3.93	3.44	3.06	2.75	2.24	1.86	1.39	1.09	0.51	0.34	0.20	1.12	123.3	5.68	2.52
.072	7.54	6.43	6.02	5.62	5.29	4.94	4.62	3.97	3.49	3.10	2.78	2.27	1.91	1.41	1.11	0.52	0.34	0.20	1.13	125.4	5.74	2.53
.074	7.62	6.50	6.08	5.68	5.35	4.99	4.67	4.02	3.53	3.14	2.82	2.30	1.92	1.44	1.13	0.54	0.35	0.21	1.14	127.5	5.80	2.54
.076	7.70	6.56	6.14	5.74	5.40	5.04	4.72	4.06	3.58	3.17	2.86	2.33	1.94	1.46	1.15	0.55	0.36	0.21	1.15	129.7	5.86	2.55
.078	7.78	6.63	6.20	5.79	5.46	5.10	4.76	4.11	3.63	3.21	2.89	2.37	1.97	1.49	1.17	0.56	0.36	0.21	1.16	131.8	5.92	2.55
.080	7.85	6.70	6.26	5.85	5.51	5.15	4.81	4.15	3.67	3.25	2.93	2.40	2.00	1.51	1.19	0.57	0.37	0.22	1.17	133.9	5.98	2.56

L/D_e	VALUES OF MOMENT MULTIPLIERS δ — VALUES OF ULTIMATE STRESS P_u/A_g IN KSI																					
	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02
3.0	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.05	1.05
4.0	1.00	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.07	1.08	1.08	1.09
5.0	1.00	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.06	1.08	1.09	1.10	1.11	1.13	1.14	1.15
6.0	1.01	1.01	1.02	1.02	1.03	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.08	1.09	1.10	1.11	1.13	1.15	1.17	1.19	1.21	1.23
7.0	1.01	1.02	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.16	1.19	1.22	1.25	1.28	1.31	1.35
8.0	1.01	1.02	1.03	1.04	1.05	1.07	1.08	1.09	1.10	1.12	1.13	1.14	1.16	1.17	1.18	1.22	1.26	1.30	1.35	1.40	1.45	1.51
9.0	1.01	1.03	1.04	1.06	1.07	1.09	1.10	1.12	1.13	1.15	1.17	1.19	1.21	1.23	1.25	1.30	1.36	1.42	1.49	1.57	1.65	1.74
10.0	1.02	1.03	1.05	1.07	1.09	1.11	1.13	1.15	1.17	1.19	1.22	1.24	1.27	1.29	1.32	1.40	1.48	1.57	1.68	1.80	1.95	2.11
11.0	1.02	1.04	1.06	1.09	1.11	1.13	1.16	1.19	1.21	1.24	1.28	1.31	1.34	1.38	1.42	1.52	1.65	1.79	1.96	2.17	2.43	2.76
12.0	1.02	1.05	1.08	1.10	1.13	1.16	1.20	1.23	1.27	1.30	1.35	1.39	1.44	1.49	1.54	1.69	1.88	2.11	2.40	2.79	3.34	4.14
13.0	1.03	1.06	1.09	1.12	1.16	1.20	1.24	1.28	1.33	1.38	1.43	1.49	1.55	1.62	1.70	1.92	2.21	2.61	3.17	4.06	5.62	9.13
14.0	1.03	1.07	1.11	1.15	1.19	1.24	1.29	1.34	1.40	1.47	1.54	1.62	1.70	1.80	1.91	2.25	2.74	3.51	4.86	7.92		
15.0	1.04	1.08	1.12	1.17	1.22	1.28	1.34	1.41	1.49	1.57	1.67	1.78	1.90	2.04	2.21	2.76	3.70	5.58				
16.0	1.04	1.09	1.14	1.20	1.26	1.33	1.41	1.50	1.60	1.71	1.84	1.99	2.17	2.39	2.65	3.65	5.88					
17.0	1.05	1.10	1.16	1.23	1.31	1.39	1.49	1.60	1.73	1.88	2.06	2.28	2.56	2.91	3.36	5.55						
18.0	1.06	1.12	1.19	1.27	1.36	1.46	1.58	1.72	1.90	2.11	2.37	2.70	3.15	3.78	4.71							

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .75 — VALUES OF ECCENTRICITY RATIO δe/D																		Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00				
.010	5.13	4.44	4.18	3.91	3.66	3.41	3.17	2.64	2.19	1.80	1.47	1.01	0.74	0.45	0.32	0.13	0.08	0.05	1.00	65.7	4.28	2.59
.012	5.21	4.51	4.25	3.97	3.72	3.47	3.23	2.72	2.27	1.88	1.58	1.10	0.81	0.52	0.37	0.15	0.09	0.05	1.00	69.0	4.35	2.60
.014	5.29	4.58	4.32	4.04	3.79	3.54	3.30	2.79	2.35	1.95	1.67	1.19	0.89	0.58	0.42	0.17	0.11	0.06	1.00	72.3	4.41	2.62
.016	5.37	4.65	4.38	4.11	3.85	3.60	3.35	2.87	2.42	2.04	1.75	1.27	0.97	0.63	0.46	0.19	0.12	0.07	1.00	75.6	4.47	2.64
.018	5.46	4.72	4.45	4.17	3.92	3.67	3.41	2.93	2.49	2.12	1.82	1.34	1.03	0.68	0.50	0.21	0.13	0.08	1.00	78.9	4.53	2.65
.020	5.54	4.80	4.52	4.24	3.98	3.73	3.48	3.00	2.55	2.19	1.88	1.43	1.09	0.73	0.54	0.23	0.14	0.08	1.00	82.2	4.59	2.67
.022	5.62	4.87	4.59	4.30	4.04	3.80	3.54	3.07	2.61	2.26	1.93	1.46	1.16	0.78	0.58	0.25	0.16	0.09	1.00	85.5	4.66	2.68
.024	5.70	4.94	4.65	4.37	4.10	3.86	3.61	3.13	2.67	2.33	2.00	1.53	1.20	0.82	0.61	0.26	0.17	0.10	1.00	88.8	4.72	2.70
.026	5.78	5.01	4.72	4.43	4.17	3.92	3.67	3.19	2.72	2.39	2.07	1.59	1.28	0.87	0.65	0.28	0.18	0.10	1.00	92.2	4.78	2.71
.028	5.86	5.08	4.79	4.50	4.23	3.99	3.73	3.25	2.79	2.45	2.14	1.65	1.31	0.91	0.68	0.30	0.19	0.11	1.00	95.5	4.84	2.73
.030	5.94	5.15	4.86	4.56	4.29	4.05	3.79	3.31	2.85	2.50	2.20	1.70	1.36	0.95	0.72	0.31	0.20	0.12	1.00	98.8	4.91	2.74
.032	6.02	5.22	4.92	4.63	4.35	4.11	3.86	3.37	2.92	2.56	2.26	1.76	1.42	1.00	0.75	0.33	0.21	0.12	1.02	102.1	4.97	2.76
.034	6.10	5.29	4.99	4.69	4.41	4.17	3.92	3.42	2.98	2.61	2.32	1.83	1.47	1.03	0.78	0.35	0.22	0.13	1.04	105.4	5.03	2.77
.036	6.18	5.36	5.06	4.76	4.47	4.23	3.98	3.48	3.04	2.66	2.37	1.87	1.52	1.07	0.82	0.36	0.23	0.13	1.05	108.7	5.09	2.79
.038	6.26	5.43	5.13	4.82	4.53	4.29	4.04	3.54	3.10	2.71	2.43	1.90	1.57	1.10	0.85	0.38	0.24	0.14	1.07	112.0	5.15	2.80
.040	6.34	5.50	5.19	4.89	4.59	4.35	4.10	3.59	3.16	2.75	2.48	1.95	1.61	1.14	0.88	0.39	0.25	0.15	1.08	115.4	5.22	2.82
.042	6.42	5.57	5.26	4.95	4.66	4.41	4.16	3.64	3.22	2.80	2.53	2.01	1.66	1.18	0.91	0.41	0.26	0.15	1.10	118.7	5.28	2.83
.044	6.50	5.64	5.33	5.02	4.72	4.47	4.22	3.70	3.20	2.85	2.57	2.07	1.70	1.20	0.94	0.42	0.27	0.16	1.11	122.0	5.34	2.85
.046	6.58	5.71	5.39	5.08	4.78	4.53	4.28	3.75	3.26	2.89	2.62	2.12	1.74	1.24	0.96	0.44	0.28	0.16	1.13	125.3	5.40	2.86
.048	6.67	5.78	5.46	5.15	4.84	4.59	4.34	3.80	3.31	2.95	2.66	2.13	1.78	1.28	0.99	0.45	0.29	0.17	1.14	128.6	5.47	2.88
.050	6.75	5.85	5.53	5.21	4.90	4.65	4.40	3.85	3.36	3.01	2.71	2.17	1.81	1.31	1.02	0.47	0.30	0.18	1.16	131.9	5.53	2.90
.052	6.83	5.92	5.59	5.28	4.96	4.71	4.46	3.90	3.41	3.06	2.75	2.22	1.85	1.35	1.04	0.48	0.31	0.18	1.17	135.2	5.59	2.91
.054	6.91	5.99	5.66	5.34	5.01	4.77	4.52	3.95	3.46	3.12	2.79	2.26	1.87	1.39	1.07	0.49	0.32	0.19	1.19	138.5	5.65	2.93
.056	6.99	6.06	5.73	5.41	5.07	4.83	4.58	4.00	3.51	3.18	2.83	2.30	1.92	1.41	1.10	0.51	0.33	0.19	1.20	141.9	5.71	2.94
.058	7.07	6.13	5.79	5.47	5.13	4.89	4.63	4.05	3.56	3.23	2.87	2.35	1.97	1.44	1.13	0.52	0.34	0.20	1.22	145.2	5.78	2.96
.060	7.15	6.20	5.86	5.54	5.19	4.95	4.69	4.10	3.61	3.21	2.91	2.39	1.99	1.48	1.15	0.54	0.35	0.20	1.23	148.5	5.84	2.97
.062	7.23	6.27	5.93	5.60	5.25	5.01	4.75	4.15	3.66	3.26	2.95	2.43	2.02	1.51	1.18	0.55	0.36	0.21	1.24	151.8	5.90	2.99
.064	7.31	6.35	5.99	5.66	5.31	5.07	4.81	4.20	3.71	3.31	2.99	2.47	2.06	1.54	1.21	0.56	0.37	0.21	1.26	155.1	5.96	3.00
.066	7.39	6.42	6.06	5.73	5.37	5.12	4.87	4.24	3.76	3.35	3.03	2.51	2.10	1.57	1.23	0.58	0.37	0.22	1.27	158.4	6.03	3.02
.068	7.47	6.49	6.13	5.79	5.44	5.18	4.92	4.29	3.81	3.40	3.07	2.55	2.14	1.60	1.25	0.59	0.38	0.23	1.28	161.7	6.09	3.03
.070	7.55	6.56	6.19	5.86	5.50	5.24	4.98	4.34	3.85	3.44	3.12	2.59	2.18	1.63	1.28	0.60	0.39	0.23	1.30	165.1	6.15	3.05
.072	7.63	6.63	6.26	5.92	5.56	5.30	5.04	4.39	3.90	3.49	3.17	2.63	2.21	1.66	1.31	0.62	0.40	0.24	1.31	168.4	6.21	3.06
.074	7.71	6.70	6.33	5.99	5.62	5.36	5.10	4.43	3.95	3.54	3.22	2.67	2.25	1.69	1.34	0.63	0.41	0.24	1.32	171.7	6.27	3.08
.076	7.79	6.77	6.39	6.05	5.68	5.41	5.15	4.48	4.00	3.58	3.28	2.71	2.29	1.72	1.35	0.64	0.42	0.25	1.34	175.0	6.34	3.09
.078	7.87	6.84	6.46	6.11	5.74	5.47	5.21	4.53	4.05	3.63	3.33	2.75	2.32	1.74	1.38	0.65	0.43	0.25	1.35	178.3	6.40	3.11
.080	7.96	6.91	6.53	6.18	5.81	5.53	5.27	4.57	4.10	3.67	3.31	2.78	2.36	1.77	1.41	0.67	0.44	0.26	1.36	181.6	6.46	3.13

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .9 — VALUES OF ECCENTRICITY RATIO δe/D																		Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00				
.010	5.15	4.48	4.22	3.97	3.72	3.49	3.25	2.75	2.29	1.89	1.57	1.08	0.80	0.49	0.34	0.14	0.08	0.05	1.00	72.9	4.65	2.89
.012	5.23	4.56	4.30	4.04	3.79	3.57	3.34	2.83	2.39	1.98	1.68	1.19	0.88	0.56	0.40	0.16	0.10	0.06	1.00	77.7	4.72	2.91
.014	5.31	4.64	4.37	4.12	3.87	3.64	3.41	2.92	2.48	2.09	1.78	1.29	0.97	0.63	0.45	0.18	0.11	0.07	1.00	82.5	4.78	2.93
.016	5.40	4.71	4.45	4.19	3.94	3.72	3.49	3.00	2.56	2.19	1.86	1.37	1.06	0.69	0.50	0.21	0.13	0.07	1.00	87.3	4.84	2.95
.018	5.48	4.79	4.52	4.27	4.01	3.79	3.57	3.07	2.63	2.28	1.93	1.47	1.13	0.74	0.55	0.23	0.14	0.08	1.00	92.0	4.91	2.97
.020	5.56	4.87	4.59	4.34	4.08	3.86	3.64	3.15	2.71	2.36	2.02	1.52	1.20	0.81	0.59	0.25	0.16	0.09	1.00	96.8	4.97	2.99
.022	5.64	4.94	4.67	4.41	4.15	3.93	3.72	3.22	2.79	2.43	2.11	1.60	1.26	0.85	0.63	0.27	0.17	0.10	1.02	101.6	5.04	3.01
.024	5.73	5.02	4.74	4.49	4.22	4.00	3.79	3.28	2.86	2.50	2.19	1.67	1.34	0.91	0.67	0.29	0.18	0.10	1.04	106.3	5.10	3.03
.026	5.81	5.09	4.81	4.56	4.30	4.07	3.86	3.35	2.93	2.57	2.27	1.74	1.38	0.96	0.72	0.31	0.20	0.11	1.06	111.1	5.16	3.05
.028	5.89	5.17	4.88	4.63	4.37	4.14	3.93	3.41	3.00	2.63	2.34	1.83	1.45	1.01	0.76	0.33	0.21	0.12	1.09	115.9	5.23	3.07
.030	5.97	5.25	4.96	4.70	4.44	4.20	3.99	3.47	3.07	2.69	2.40	1.88	1.51	1.06	0.80	0.35	0.22	0.13	1.11	120.7	5.29	3.09
.032	6.05	5.32	5.03	4.77	4.51	4.27	4.06	3.53	3.14	2.76	2.47	1.93	1.57	1.11	0.84	0.37	0.23	0.13	1.13	125.4	5.36	3.11
.034	6.14	5.40	5.10	4.85	4.58	4.33	4.13	3.59	3.20	2.83	2.53	2.00	1.63	1.14	0.88	0.39	0.25	0.14	1.15	130.2	5.42	3.13
.036	6.22	5.47	5.17	4.92	4.65	4.40	4.19	3.66	3.27	2.89	2.58	2.07	1.68	1.19	0.91	0.40	0.26	0.15	1.17	135.0	5.48	3.15
.038	6.30	5.55	5.24	4.99	4.72	4.46	4.26	3.73	3.33	2.95	2.64	2.14	1.74	1.23	0.95	0.42	0.27	0.16	1.19	139.7	5.55	3.17
.040	6.38	5.62	5.32	5.06	4.79	4.52	4.32	3.79	3.39	3.02	2.69	2.20	1.78	1.28	0.99	0.44	0.28	0.16	1.21	144.5	5.61	3.19
.042	6.46	5.70	5.39	5.13	4.86	4.58	4.39	3.86	3.45	3.08	2.74	2.22	1.85	1.33	1.02	0.46	0.29	0.17	1.23	149.3	5.68	3.21
.044	6.55	5.77	5.46	5.20	4.93	4.65	4.45	3.93	3.51	3.14	2.79	2.27	1.88	1.36	1.05	0.48	0.31	0.18	1.25	154.1	5.74	3.23
.046	6.63	5.85	5.54	5.27	5.00	4.72	4.51	3.99	3.56	3.20	2.85	2.32	1.93	1.40	1.08	0.49	0.32	0.18	1.27	158.8	5.80	3.25
.048	6.71	5.92	5.61	5.33	5.07	4.79	4.57	4.06	3.62	3.25	2.91	2.38	1.99	1.44	1.12	0.51	0.33	0.19	1.29	163.6	5.87	3.27
.050	6.79	6.00	5.68	5.40	5.14	4.86	4.64	4.12	3.67	3.31	2.97	2.43	2.02	1.48	1.16	0.53	0.34	0.20	1.31	168.4	5.93	3.29
.052	6.87	6.07	5.76	5.47	5.21	4.93	4.70	4.19	3.73	3.37	3.03	2.48	2.06	1.52	1.18	0.55	0.35	0.20	1.33	173.1	6.00	3.31
.054	6.95	6.15	5.83	5.54	5.27	4.99	4.76	4.25	3.78	3.43	3.08	2.53	2.11	1.56	1.22	0.56	0.36	0.21	1.35	177.9	6.06	3.33
.056	7.03	6.22	5.90	5.61	5.34	5.06	4.82	4.31	3.83	3.48	3.14	2.58	2.16	1.60	1.25	0.58	0.37	0.22	1.36	182.7	6.12	3.35
.058	7.12	6.30	5.97	5.68	5.41	5.13	4.88	4.37	3.88	3.54	3.19	2.66	2.20	1.64	1.28	0.59	0.38	0.22	1.38	187.5	6.19	3.37
.060	7.20	6.37	6.05	5.75	5.48	5.19	4.94	4.44	3.93	3.59	3.25	2.71	2.25	1.68	1.32	0.61	0.40	0.23	1.40	192.2	6.25	3.39
.062	7.28	6.45	6.12	5.81	5.55	5.26	5.00	4.50	3.98	3.65	3.30	2.75	2.30	1.71	1.34	0.63	0.41	0.24	1.42	197.0	6.31	3.41
.064	7.37	6.52	6.19	5.88	5.61	5.33	5.06	4.56	4.03	3.70	3.35	2.79	2.34	1.75	1.37	0.64	0.42	0.24	1.43	201.8	6.38	3.43
.066	7.45	6.59	6.26	5.95	5.68	5.39	5.12	4.62	4.08	3.75	3.41	2.83	2.38	1.79	1.40	0.66	0.43	0.25	1.45	206.5	6.44	3.45
.068	7.53	6.67	6.34	6.02	5.75	5.46	5.18	4.68	4.14	3.80	3.46	2.87	2.43	1.82	1.44	0.68	0.44	0.26	1.47	211.3	6.51	3.47
.070	7.62	6.74	6.41	6.08	5.81	5.53	5.23	4.74	4.20	3.85	3.51	2.90	2.47	1.85	1.47	0.69	0.45	0.26	1.48	216.1	6.57	3.49
.072	7.70	6.82	6.48	6.15	5.88	5.59	5.29	4.80	4.26	3.90	3.56	2.94	2.51	1.90	1.50	0.71	0.46	0.27	1.50	220.9	6.63	3.51
.074	7.79	6.89	6.55	6.22	5.95	5.66	5.36	4.86	4.32	3.95	3.62	2.99	2.56	1.91	1.53	0.72	0.47	0.28	1.52	225.6	6.70	3.53
.076	7.87	6.96	6.62	6.29	6.01	5.72	5.42	4.91	4.38	4.00	3.60	3.04	2.60	1.95	1.56	0.74	0.48	0.28	1.53	230.4	6.76	3.55
.078	7.95	7.04	6.70	6.35	6.08	5.79	5.49	4.97	4.44	4.05	3.65	3.09	2.64	1.98	1.58	0.75	0.49	0.29	1.55	235.2	6.83	3.57
.080	8.04	7.11	6.77	6.42	6.15	5.86	5.55	5.03	4.50	4.09	3.70	3.14	2.68	2.02	1.61	0.77	0.50	0.29	1.56	239.9	6.89	3.59

Table 6.7A.4 Values of ultimate axial stress, P_u/A_g, for circular column, f'_c = 3 ksi, f_{dy} = 72 ksi, γ = 0.45, 0.60, 0.75, 0.90



p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .45																		Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO $\delta e/D$																					
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00				
.010	3.34	2.85	2.65	2.46	2.26	2.09	1.91	1.58	1.28	1.09	0.93	0.70	0.56	0.39	0.29	0.13	0.08	0.05	1.00	35.4	2.39	0.94
.012	3.44	2.93	2.72	2.52	2.31	2.14	1.96	1.63	1.32	1.13	0.98	0.75	0.61	0.42	0.32	0.15	0.09	0.05	1.00	36.6	2.45	0.91
.014	3.54	3.00	2.79	2.58	2.36	2.19	2.01	1.67	1.38	1.17	1.01	0.79	0.63	0.45	0.35	0.16	0.10	0.06	1.00	37.8	2.52	0.87
.016	3.65	3.08	2.86	2.64	2.42	2.24	2.05	1.72	1.43	1.21	1.05	0.82	0.67	0.48	0.37	0.17	0.11	0.07	1.00	39.0	2.59	0.84
.018	3.75	3.16	2.92	2.70	2.47	2.29	2.10	1.76	1.43	1.25	1.09	0.86	0.70	0.50	0.39	0.18	0.12	0.07	1.00	40.2	2.65	0.81
.020	3.85	3.24	2.99	2.76	2.53	2.34	2.15	1.75	1.46	1.26	1.11	0.88	0.72	0.53	0.41	0.19	0.13	0.08	1.00	41.4	2.72	0.78
.022	3.95	3.31	3.06	2.81	2.58	2.39	2.19	1.80	1.50	1.28	1.14	0.91	0.75	0.55	0.43	0.20	0.13	0.08	1.00	42.6	2.78	0.75
.024	4.05	3.39	3.13	2.87	2.63	2.44	2.24	1.84	1.54	1.34	1.17	0.93	0.77	0.57	0.45	0.21	0.14	0.08	1.00	43.8	2.85	0.72
.026	4.15	3.46	3.20	2.93	2.69	2.49	2.28	1.87	1.58	1.34	1.20	0.96	0.79	0.59	0.47	0.22	0.15	0.09	1.00	45.0	2.91	0.69
.028	4.25	3.54	3.27	2.99	2.74	2.54	2.33	1.91	1.62	1.38	1.23	0.98	0.82	0.61	0.48	0.23	0.15	0.09	1.00	46.2	2.98	0.65
.030	4.35	3.62	3.33	3.05	2.80	2.59	2.38	1.95	1.66	1.41	1.26	1.00	0.84	0.63	0.50	0.24	0.16	0.10	1.00	47.3	3.04	0.62
.032	4.43	3.69	3.40	3.11	2.85	2.64	2.42	1.99	1.69	1.44	1.26	1.03	0.86	0.64	0.51	0.25	0.16	0.10	1.00	48.5	3.11	0.59
.034	4.56	3.77	3.47	3.17	2.90	2.69	2.47	2.03	1.73	1.48	1.30	1.05	0.88	0.66	0.52	0.26	0.17	0.10	1.00	49.7	3.18	0.56
.036	4.66	3.84	3.54	3.23	2.96	2.74	2.52	2.07	1.77	1.51	1.31	1.07	0.90	0.67	0.54	0.26	0.17	0.10	1.00	50.9	3.24	0.53
.038	4.76	3.92	3.60	3.28	3.01	2.79	2.56	2.11	1.77	1.55	1.34	1.08	0.90	0.69	0.55	0.27	0.18	0.11	1.00	52.1	3.31	0.50
.040	4.86	3.99	3.67	3.34	3.07	2.84	2.61	2.15	1.80	1.58	1.37	1.10	0.92	0.70	0.56	0.28	0.18	0.11	1.00	53.3	3.37	0.47
.042	4.96	4.07	3.74	3.40	3.12	2.90	2.66	2.19	1.84	1.58	1.40	1.12	0.94	0.71	0.57	0.28	0.19	0.11	1.00	54.5	3.44	0.43
.044	5.06	4.14	3.81	3.46	3.18	2.95	2.70	2.23	1.87	1.61	1.43	1.14	0.96	0.73	0.58	0.29	0.19	0.12	1.00	55.7	3.50	0.40
.046	5.16	4.22	3.87	3.51	3.23	3.00	2.75	2.26	1.91	1.64	1.46	1.17	0.97	0.74	0.59	0.30	0.20	0.12	1.00	56.9	3.57	0.37
.048	5.26	4.29	3.94	3.57	3.28	3.05	2.80	2.30	1.94	1.68	1.49	1.19	1.00	0.76	0.60	0.31	0.20	0.12	1.00	58.1	3.63	0.34
.050	5.37	4.36	4.01	3.63	3.34	3.10	2.84	2.34	1.98	1.71	1.49	1.21	1.02	0.77	0.62	0.31	0.21	0.12	1.00	59.3	3.70	0.31
.052	5.47	4.44	4.07	3.69	3.39	3.15	2.89	2.38	2.01	1.74	1.52	1.23	1.03	0.78	0.63	0.32	0.21	0.13	1.01	60.5	3.77	0.28
.054	5.57	4.51	4.14	3.74	3.45	3.20	2.94	2.42	2.05	1.77	1.55	1.25	1.05	0.80	0.64	0.32	0.22	0.13	1.02	61.7	3.83	0.24
.056	5.67	4.59	4.21	3.80	3.50	3.25	2.98	2.45	2.08	1.80	1.58	1.27	1.06	0.81	0.65	0.33	0.22	0.13	1.03	62.9	3.90	0.21
.058	5.77	4.66	4.27	3.86	3.56	3.30	3.03	2.49	2.12	1.83	1.60	1.29	1.08	0.82	0.66	0.33	0.22	0.13	1.04	64.0	3.96	0.18
.060	5.87	4.73	4.34	3.91	3.61	3.35	3.08	2.53	2.15	1.87	1.63	1.31	1.10	0.84	0.67	0.34	0.23	0.14	1.05	65.2	4.03	0.15
.062	5.97	4.81	4.41	3.97	3.67	3.40	3.13	2.57	2.19	1.90	1.66	1.34	1.12	0.85	0.68	0.34	0.23	0.14	1.06	66.4	4.09	0.12
.064	6.07	4.88	4.47	4.03	3.72	3.45	3.17	2.60	2.23	1.90	1.69	1.36	1.14	0.86	0.70	0.35	0.24	0.14	1.07	67.6	4.16	0.09
.066	6.18	4.95	4.54	4.08	3.77	3.50	3.22	2.64	2.23	1.93	1.72	1.39	1.16	0.88	0.70	0.36	0.24	0.14	1.08	68.8	4.22	0.06
.068	6.28	5.03	4.61	4.14	3.83	3.56	3.27	2.68	2.26	1.96	1.75	1.39	1.17	0.89	0.71	0.36	0.24	0.18	1.09	70.0	4.29	0.02
.070	6.38	5.10	4.67	4.20	3.88	3.61	3.31	2.72	2.29	1.99	1.75	1.41	1.19	0.91	0.73	0.37	0.25	0.15	1.10	71.2	4.36	-.01
.072	6.48	5.17	4.74	4.25	3.94	3.66	3.36	2.75	2.33	2.02	1.78	1.44	1.21	0.91	0.74	0.37	0.25	0.15	1.11	72.4	4.42	-.04
.074	6.58	5.25	4.81	4.31	3.99	3.71	3.41	2.79	2.36	2.05	1.80	1.46	1.22	0.93	0.75	0.38	0.25	0.15	1.12	73.6	4.49	-.07
.076	6.68	5.32	4.87	4.36	4.05	3.76	3.45	2.83	2.40	2.08	1.83	1.48	1.24	0.94	0.76	0.39	0.26	0.16	1.13	74.8	4.55	-.10
.078	6.78	5.39	4.94	4.42	4.10	3.81	3.50	2.86	2.43	2.11	1.86	1.50	1.26	0.96	0.77	0.39	0.26	0.16	1.14	76.0	4.62	-.13
.080	6.89	5.47	5.00	4.48	4.16	3.86	3.55	2.90	2.46	2.14	1.88	1.53	1.28	0.97	0.78	0.40	0.27	0.16	1.14	77.2	4.68	-.16

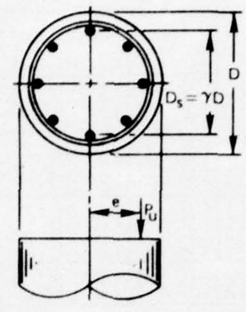
p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6																		Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO $\delta e/D$																					
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00				
.010	3.36	2.90	2.71	2.54	2.36	2.20	2.05	1.72	1.46	1.23	1.05	0.80	0.63	0.43	0.32	0.14	0.09	0.05	1.00	40.1	2.69	1.21
.012	3.47	2.99	2.80	2.62	2.44	2.27	2.12	1.78	1.49	1.27	1.11	0.85	0.69	0.47	0.36	0.16	0.10	0.06	1.00	42.2	2.76	1.20
.014	3.57	3.08	2.88	2.70	2.51	2.34	2.19	1.83	1.55	1.35	1.19	0.92	0.73	0.52	0.39	0.18	0.11	0.07	1.00	44.3	2.84	1.19
.016	3.68	3.17	2.96	2.77	2.59	2.40	2.26	1.89	1.61	1.38	1.23	0.97	0.78	0.56	0.43	0.19	0.12	0.07	1.00	46.4	2.91	1.18
.018	3.79	3.26	3.05	2.85	2.66	2.47	2.33	1.94	1.67	1.44	1.27	1.01	0.82	0.59	0.45	0.21	0.13	0.08	1.00	48.5	2.99	1.17
.020	3.90	3.35	3.13	2.93	2.73	2.54	2.39	2.00	1.73	1.49	1.33	1.06	0.87	0.63	0.48	0.22	0.14	0.08	1.00	50.7	3.07	1.17
.022	4.01	3.44	3.21	3.01	2.81	2.61	2.46	2.06	1.78	1.55	1.36	1.10	0.91	0.66	0.51	0.24	0.15	0.09	1.00	52.8	3.14	1.16
.024	4.11	3.53	3.30	3.09	2.88	2.67	2.52	2.13	1.84	1.60	1.40	1.14	0.95	0.69	0.54	0.25	0.16	0.10	1.00	54.9	3.22	1.15
.026	4.22	3.62	3.38	3.16	2.96	2.74	2.59	2.19	1.89	1.65	1.45	1.18	0.99	0.73	0.56	0.27	0.17	0.10	1.00	57.0	3.29	1.14
.028	4.33	3.71	3.46	3.24	3.03	2.81	2.66	2.26	1.95	1.71	1.50	1.23	1.02	0.76	0.59	0.28	0.18	0.11	1.00	59.1	3.37	1.13
.030	4.44	3.80	3.55	3.32	3.10	2.88	2.72	2.32	2.00	1.76	1.55	1.25	1.06	0.79	0.62	0.29	0.19	0.11	1.02	61.3	3.45	1.13
.032	4.55	3.89	3.63	3.40	3.18	2.94	2.78	2.38	2.05	1.82	1.60	1.30	1.09	0.81	0.64	0.31	0.20	0.12	1.04	63.4	3.52	1.12
.034	4.66	3.98	3.71	3.48	3.25	3.01	2.85	2.45	2.10	1.83	1.62	1.32	1.13	0.84	0.67	0.32	0.21	0.12	1.05	65.5	3.60	1.11
.036	4.77	4.07	3.80	3.55	3.33	3.08	2.91	2.51	2.18	1.88	1.67	1.36	1.16	0.87	0.69	0.33	0.22	0.13	1.07	67.6	3.67	1.10
.038	4.87	4.16	3.88	3.63	3.40	3.15	2.98	2.57	2.23	1.93	1.71	1.40	1.19	0.90	0.71	0.34	0.22	0.13	1.09	69.7	3.75	1.09
.040	4.98	4.25	3.97	3.71	3.47	3.22	3.04	2.63	2.27	1.98	1.76	1.44	1.22	0.92	0.73	0.36	0.23	0.14	1.10	71.9	3.82	1.08
.042	5.09	4.34	4.05	3.79	3.55	3.29	3.10	2.69	2.31	2.03	1.80	1.48	1.25	0.95	0.76	0.37	0.24	0.14	1.12	74.0	3.90	1.08
.044	5.20	4.43	4.13	3.86	3.62	3.36	3.17	2.75	2.36	2.08	1.85	1.50	1.26	0.97	0.78	0.38	0.25	0.15	1.14	76.1	3.98	1.07
.046	5.31	4.52	4.22	3.94	3.70	3.43	3.23	2.81	2.40	2.12	1.89	1.54	1.30	1.00	0.80	0.39	0.26	0.15	1.15	78.2	4.05	1.06
.048	5.42	4.61	4.30	4.02	3.77	3.50	3.29	2.80	2.44	2.17	1.94	1.57	1.33	1.01	0.81	0.40	0.26	0.16	1.17	80.3	4.13	1.05
.050	5.53	4.70	4.39	4.09	3.84	3.57	3.36	2.86	2.48	2.22	1.98	1.61	1.36	1.04	0.83	0.41	0.27	0.16	1.18	82.5	4.20	1.04
.052	5.64	4.79	4.47	4.17	3.92	3.64	3.42	2.92	2.52	2.26	2.03	1.65	1.40	1.06	0.86	0.42	0.28	0.17	1.20	84.6	4.28	1.04
.054	5.75	4.88	4.55	4.25	3.99	3.71	3.48	2.97	2.58	2.31	2.05	1.69	1.42	1.08	0.88	0.44	0.29	0.17	1.21	86.7	4.35	1.03
.056	5.86	4.97	4.64	4.33	4.06	3.78	3.55	3.03	2.64	2.35	2.09	1.73	1.45	1.11	0.90	0.45	0.30	0.18	1.23	88.8	4.43	1.02
.058	5.96	5.06	4.72	4.40	4.14	3.85	3.61	3.09	2.69	2.40	2.13	1.74	1.48	1.13	0.91	0.46	0.30	0.18	1.24	90.9	4.51	1.01
.060	6.07	5.15	4.81	4.48	4.21	3.92	3.67	3.14	2.75	2.45	2.18	1.78	1.51	1.16	0.93	0.47	0.31	0.18	1.26	93.1	4.58	1.00
.062	6.18	5.24	4.89	4.56	4.28	3.99	3.73	3.20	2.81	2.49	2.22	1.82	1.54	1.18	0.95	0.48	0.32	0.19	1.27	95.2	4.66	0.99
.064	6.29	5.33	4.97	4.64	4.36	4.06	3.80	3.26	2.86	2.53	2.26	1.85	1.58	1.20	0.97	0.49	0.32	0.19	1.29	97.3	4.73	0.99
.066	6.40	5.42	5.06	4.71	4.43	4.13	3.86	3.31	2.92	2.58	2.30	1.89	1.61	1.22	0.99	0.50	0.33	0.20	1.30	99.4	4.81	0.98
.068	6.51	5.51	5.14	4.79	4.51	4.20	3.92	3.37	2.98	2.62	2.35	1.93	1.62	1.24	1.01	0.51	0.34	0.20	1.31	101.6	4.89	0.97
070	6.62	5.60	5.23	4.87	4.58	4.27	3.98	3.43	3.03	2.67	2.39	1.96	1.65	1.27	1.03	0.52	0.35	0.21	1.33	103.7	4.96	0.96
.072	6.73	5.69	5.31	4.94	4.65	4.34	4.04	3.48	3.09	2.71	2.43	2.00	1.68	1.29	1.05	0.53	0.35	0.21	1.34	105.8	5.04	0.95
.074	6.84	5.78	5.39	5.02	4.73	4.41	4.11	3.54	3.14	2.76	2.47	2.04	1.72	1.32	1.07	0.54	0.36	0.22	1.35	107.9	5.11	0.94
.076	6.95	5.86	5.48	5.10	4.80	4.48	4.17	3.60	3.12	2.80	2.52	2.05	1.75	1.33	1.09	0.55	0.37	0.22	1.37	110.0	5.19	0.94
.078	7.06	5.95	5.56	5.18	4.87	4.55	4.23	3.65	3.17	2.87	2.56	2.09	1.78	1.36	1.10	0.56	0.37	0.22	1.38	112.2	5.26	0.93
.080	7.17	6.04	5.65	5.25	4.95	4.62	4.29	3.71	3.22	2.91	2.60	2.13	1.81	1.38	1.12	0.57	0.38	0.23	1.39	114.3	5.34	0.92

L/D_e	VALUES OF MOMENT MULTIPLIERS δ — VALUES OF ULTIMATE STRESS P_u/A_g IN KSI: 0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04
3.0	1.00	1.00	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.09
4.0	1.00	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.05	1.06	1.06	1.07	1.08	1.09	1.11	1.12	1.13	1.15	1.16
5.0	1.01	1.01	1.02	1.03	1.03	1.04	1.05	1.06	1.06	1.07	1.08	1.09	1.10	1.10	1.11	1.13	1.16	1.18	1.20	1.23	1.25	1.28
6.0	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.10	1.11	1.12	1.13	1.14	1.16	1.17	1.21	1.24	1.28	1.32	1.37	1.41	1.46
7.0	1.01	1.03	1.04	1.06	1.07	1.09	1.10	1.12	1.14	1.15	1.17	1.19	1.21	1.23	1.25	1.30	1.36	1.42	1.49	1.57	1.66	1.76
8.0	1.02	1.04	1.05	1.07	1.09	1.12	1.14	1.16	1.18	1.21	1.23	1.26	1.29	1.32	1.35	1.43	1.53	1.64	1.76	1.91	2.08	2.28
9.0	1.02	1.05	1.07	1.10	1.12	1.15	1.18	1.21	1.25	1.28	1.32	1.36	1.40	1.44	1.49	1.62	1.78	1.97	2.21	2.51	2.91	3.46
10.0	1.03	1.06	1.09	1.12	1.16	1.19	1.23	1.28	1.32	1.37	1.42	1.48	1.54	1.61	1.68	1.90	2.18	2.55	3.08	3.89	5.28	8.20
11.0	1.03	1.07	1.11	1.15	1.20	1.24	1.30	1.35	1.42	1.49	1.56	1.65	1.74	1.84	1.96	2.34	2.89	3.78	5.47	9.91		
12.0	1.04	1.08	1.13	1.18	1.24	1.30	1.37	1.45	1.54	1.64	1.75	1.88	2.02	2.20	2.40	3.13	4.51	8.03				
13.0	1.05	1.10	1.16	1.22	1.30	1.38	1.47	1.58	1.70	1.84	2.01	2.21	2.46	2.77	3.17	4.98						
14.0	1.06	1.12	1.19	1.27	1.36	1.47	1.59	1.74	1.91	2.13	2.40	2.74	3.21	3.87	4.86							
15.0	1.06	1.14	1.22	1.32	1.44	1.57	1.74	1.95	2.21	2.55	3.02	3.70	4.77	6.72								
16.0	1.07	1.16	1.26	1.38	1.53	1.71	1.96	2.24	2.65	3.24	4.18	5.88	9.92									
17.0	1.08	1.19	1.31	1.45	1.64	1.88	2.21	2.66	3.36	4.56	7.09											
18.0	1.10	1.21	1.36	1.54	1.78	2.11	2.58	3.34	4.71	8.03												

p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .75$ — VALUES OF ECCENTRICITY RATIO $\delta e/D$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s = 0$	P_u/A_g at $\epsilon_s = \epsilon_y$
.010	3.39	2.95	2.78	2.61	2.45	2.29	2.15	1.82	1.59	1.36	1.19	0.91	0.70	0.47	0.35	0.15	0.10	0.06	1.00	46.0	2.95	1.44
.012	3.50	3.05	2.88	2.70	2.54	2.38	2.24	1.91	1.67	1.45	1.26	0.97	0.77	0.54	0.40	0.17	0.11	0.06	1.00	49.3	3.03	1.45
.014	3.62	3.15	2.97	2.79	2.63	2.47	2.31	2.00	1.74	1.54	1.33	1.05	0.84	0.59	0.45	0.20	0.13	0.07	1.00	52.6	3.11	1.46
.016	3.73	3.25	3.07	2.87	2.72	2.55	2.39	2.08	1.81	1.57	1.41	1.12	0.91	0.64	0.49	0.22	0.14	0.08	1.00	56.0	3.19	1.47
.018	3.84	3.34	3.16	2.96	2.80	2.64	2.47	2.16	1.87	1.64	1.46	1.18	0.97	0.69	0.53	0.24	0.15	0.09	1.00	59.3	3.27	1.47
.020	3.95	3.44	3.25	3.06	2.89	2.72	2.55	2.24	1.92	1.71	1.52	1.24	1.02	0.74	0.57	0.26	0.17	0.10	1.03	62.6	3.35	1.48
.022	4.07	3.54	3.35	3.15	2.97	2.81	2.63	2.32	2.00	1.77	1.58	1.29	1.08	0.78	0.61	0.28	0.18	0.10	1.06	65.9	3.43	1.49
.024	4.18	3.64	3.44	3.24	3.06	2.89	2.72	2.39	2.08	1.84	1.65	1.37	1.13	0.83	0.64	0.30	0.19	0.11	1.08	69.2	3.52	1.50
.026	4.29	3.74	3.54	3.33	3.14	2.97	2.80	2.46	2.15	1.90	1.71	1.40	1.19	0.87	0.68	0.32	0.21	0.12	1.11	72.5	3.60	1.50
.028	4.40	3.84	3.63	3.42	3.23	3.06	2.88	2.53	2.23	1.98	1.77	1.45	1.24	0.91	0.72	0.34	0.22	0.13	1.13	75.8	3.68	1.51
.030	4.52	3.93	3.72	3.51	3.31	3.14	2.96	2.60	2.30	2.03	1.83	1.50	1.27	0.95	0.75	0.35	0.23	0.13	1.16	79.2	3.76	1.52
.032	4.63	4.03	3.82	3.60	3.39	3.22	3.04	2.67	2.37	2.08	1.88	1.55	1.31	0.99	0.78	0.37	0.24	0.14	1.18	82.5	3.84	1.53
.034	4.74	4.13	3.91	3.69	3.47	3.30	3.12	2.74	2.39	2.13	1.94	1.61	1.36	1.03	0.81	0.39	0.25	0.15	1.21	85.8	3.92	1.53
.036	4.86	4.23	4.00	3.78	3.56	3.38	3.20	2.81	2.45	2.19	1.99	1.66	1.40	1.07	0.85	0.40	0.26	0.16	1.23	89.1	4.00	1.54
.038	4.97	4.33	4.10	3.87	3.64	3.46	3.28	2.88	2.52	2.26	2.05	1.71	1.45	1.11	0.88	0.42	0.28	0.16	1.25	92.4	4.08	1.55
.040	5.08	4.43	4.19	3.96	3.72	3.54	3.36	2.95	2.58	2.33	2.10	1.74	1.49	1.14	0.91	0.44	0.29	0.17	1.27	95.7	4.16	1.56
.042	5.19	4.53	4.28	4.05	3.80	3.62	3.44	3.01	2.65	2.40	2.15	1.79	1.54	1.18	0.94	0.46	0.30	0.18	1.30	99.0	4.24	1.56
.044	5.31	4.63	4.37	4.14	3.89	3.70	3.52	3.08	2.71	2.46	2.20	1.84	1.58	1.22	0.97	0.47	0.31	0.18	1.32	102.3	4.33	1.57
.046	5.42	4.73	4.47	4.23	3.97	3.78	3.60	3.14	2.78	2.47	2.27	1.89	1.63	1.24	1.00	0.49	0.32	0.19	1.34	105.7	4.41	1.58
.048	5.53	4.83	4.56	4.32	4.06	3.86	3.67	3.21	2.84	2.53	2.31	1.93	1.65	1.27	1.03	0.50	0.33	0.20	1.36	109.0	4.49	1.59
.050	5.64	4.93	4.65	4.41	4.15	3.94	3.75	3.27	2.90	2.59	2.36	1.98	1.69	1.31	1.06	0.52	0.34	0.20	1.38	112.3	4.57	1.59
.052	5.76	5.03	4.74	4.50	4.23	4.02	3.83	3.34	2.97	2.65	2.40	2.03	1.74	1.34	1.09	0.54	0.35	0.21	1.40	115.6	4.65	1.60
.054	5.88	5.13	4.84	4.59	4.32	4.10	3.91	3.40	3.03	2.71	2.45	2.08	1.78	1.38	1.12	0.55	0.36	0.22	1.42	118.9	4.73	1.61
.056	6.00	5.23	4.93	4.68	4.40	4.18	3.98	3.46	3.09	2.77	2.51	2.12	1.82	1.41	1.15	0.57	0.37	0.22	1.44	122.2	4.81	1.62
.058	6.12	5.33	5.02	4.77	4.49	4.26	4.06	3.53	3.16	2.83	2.58	2.17	1.86	1.45	1.17	0.58	0.38	0.23	1.46	125.5	4.89	1.63
.060	6.24	5.43	5.11	4.85	4.58	4.34	4.14	3.59	3.22	2.88	2.64	2.22	1.91	1.49	1.20	0.60	0.40	0.23	1.48	128.9	4.97	1.63
.062	6.36	5.53	5.20	4.94	4.66	4.42	4.21	3.67	3.28	2.94	2.70	2.26	1.95	1.51	1.22	0.61	0.41	0.24	1.50	132.2	5.06	1.64
.064	6.48	5.63	5.30	5.03	4.75	4.49	4.29	3.74	3.34	3.00	2.71	2.31	1.97	1.54	1.25	0.64	0.43	0.25	1.52	135.5	5.14	1.65
.066	6.59	5.73	5.39	5.12	4.83	4.57	4.37	3.81	3.41	3.06	2.76	2.35	2.01	1.57	1.28	0.64	0.43	0.25	1.54	138.8	5.22	1.66
.068	6.71	5.83	5.48	5.21	4.92	4.65	4.44	3.88	3.47	3.12	2.81	2.40	2.05	1.60	1.31	0.66	0.44	0.26	1.55	142.1	5.30	1.66
.070	6.83	5.93	5.57	5.30	5.00	4.73	4.52	3.95	3.53	3.17	2.86	2.44	2.09	1.64	1.34	0.67	0.45	0.27	1.57	145.4	5.38	1.67
.072	6.94	6.02	5.67	5.39	5.09	4.81	4.60	4.03	3.59	3.23	2.92	2.49	2.14	1.67	1.37	0.69	0.46	0.27	1.59	148.7	5.46	1.68
.074	7.06	6.12	5.76	5.48	5.18	4.88	4.67	4.10	3.65	3.29	2.97	2.53	2.18	1.70	1.38	0.70	0.47	0.28	1.61	152.0	5.54	1.69
.076	7.18	6.22	5.86	5.56	5.26	4.96	4.75	4.17	3.71	3.35	3.02	2.57	2.22	1.74	1.41	0.72	0.48	0.28	1.62	155.4	5.62	1.69
.078	7.29	6.32	5.95	5.65	5.35	5.04	4.83	4.24	3.78	3.40	3.07	2.62	2.26	1.77	1.44	0.73	0.49	0.29	1.64	158.7	5.70	1.70
.080	7.41	6.42	6.05	5.74	5.43	5.12	4.90	4.31	3.84	3.46	3.13	2.66	2.30	1.79	1.47	0.75	0.50	0.30	1.66	162.0	5.79	1.71

p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI $\gamma = .9$ — VALUES OF ECCENTRICITY RATIO $\delta e/D$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s = 0$	P_u/A_g at $\epsilon_s = \epsilon_y$
.010	3.43	3.00	2.84	2.68	2.53	2.39	2.24	1.96	1.69	1.47	1.28	0.98	0.78	0.53	0.40	0.17	0.11	0.06	1.00	53.3	3.18	1.65
.012	3.54	3.11	2.95	2.78	2.63	2.49	2.34	2.05	1.77	1.57	1.38	1.08	0.87	0.60	0.45	0.19	0.12	0.07	1.00	58.1	3.27	1.66
.014	3.66	3.22	3.05	2.89	2.73	2.59	2.44	2.14	1.87	1.66	1.47	1.16	0.94	0.67	0.50	0.22	0.14	0.08	1.03	62.9	3.35	1.68
.016	3.78	3.32	3.15	2.99	2.82	2.68	2.54	2.23	1.97	1.74	1.56	1.25	1.02	0.73	0.56	0.25	0.16	0.09	1.07	67.6	3.43	1.69
.018	3.89	3.43	3.25	3.09	2.91	2.77	2.63	2.31	2.06	1.81	1.64	1.32	1.09	0.78	0.61	0.27	0.17	0.10	1.11	72.4	3.52	1.71
.020	4.01	3.54	3.36	3.19	3.01	2.87	2.73	2.39	2.15	1.89	1.71	1.40	1.16	0.84	0.65	0.30	0.19	0.11	1.14	77.2	3.60	1.73
.022	4.13	3.65	3.45	3.29	3.11	2.96	2.82	2.47	2.23	1.98	1.78	1.48	1.23	0.89	0.69	0.32	0.21	0.12	1.18	81.9	3.69	1.74
.024	4.24	3.75	3.55	3.39	3.21	3.04	2.91	2.54	2.31	2.06	1.85	1.52	1.28	0.95	0.74	0.34	0.22	0.13	1.21	86.7	3.77	1.76
.026	4.35	3.86	3.65	3.48	3.31	3.13	2.99	2.63	2.39	2.10	1.91	1.59	1.35	1.00	0.78	0.37	0.24	0.14	1.25	91.5	3.86	1.78
.028	4.47	3.96	3.76	3.58	3.40	3.22	3.08	2.72	2.46	2.18	1.97	1.65	1.40	1.05	0.83	0.39	0.25	0.15	1.28	96.3	3.94	1.79
.030	4.59	4.07	3.86	3.68	3.50	3.31	3.17	2.80	2.53	2.25	2.05	1.72	1.46	1.10	0.87	0.41	0.27	0.16	1.31	101.0	4.03	1.81
.032	4.71	4.17	3.96	3.77	3.59	3.40	3.25	2.89	2.61	2.32	2.13	1.77	1.51	1.15	0.91	0.43	0.28	0.16	1.34	105.8	4.11	1.83
.034	4.84	4.28	4.07	3.87	3.69	3.50	3.34	2.97	2.68	2.39	2.17	1.83	1.57	1.19	0.95	0.45	0.29	0.17	1.37	110.6	4.19	1.84
.036	4.96	4.38	4.17	3.96	3.78	3.59	3.42	3.06	2.74	2.46	2.23	1.89	1.63	1.24	0.99	0.47	0.31	0.18	1.40	115.3	4.28	1.86
.038	5.08	4.49	4.27	4.06	3.88	3.68	3.50	3.14	2.81	2.53	2.30	1.97	1.68	1.29	1.03	0.49	0.32	0.19	1.43	120.1	4.36	1.88
.040	5.20	4.59	4.37	4.15	3.97	3.77	3.59	3.22	2.88	2.60	2.36	2.02	1.73	1.32	1.06	0.51	0.34	0.20	1.46	124.9	4.45	1.89
.042	5.32	4.70	4.48	4.25	4.06	3.87	3.67	3.31	2.94	2.67	2.43	2.07	1.78	1.37	1.10	0.54	0.35	0.21	1.48	129.6	4.53	1.91
.044	5.44	4.80	4.58	4.34	4.16	3.96	3.75	3.39	3.01	2.74	2.49	2.12	1.83	1.41	1.14	0.56	0.36	0.21	1.51	134.4	4.62	1.92
.046	5.55	4.90	4.68	4.44	4.25	4.05	3.84	3.47	3.07	2.80	2.56	2.16	1.88	1.46	1.18	0.58	0.38	0.22	1.54	139.2	4.70	1.94
.048	5.67	5.01	4.78	4.53	4.34	4.14	3.93	3.55	3.15	2.87	2.62	2.23	1.93	1.50	1.22	0.60	0.39	0.23	1.56	144.0	4.79	1.96
.050	5.78	5.11	4.88	4.63	4.43	4.23	4.02	3.63	3.23	2.94	2.68	2.29	1.98	1.55	1.25	0.62	0.40	0.24	1.59	148.7	4.87	1.97
.052	5.89	5.21	4.98	4.73	4.52	4.32	4.10	3.71	3.31	3.00	2.75	2.32	2.03	1.59	1.28	0.64	0.42	0.25	1.61	153.5	4.96	1.99
.054	6.02	5.32	5.08	4.83	4.61	4.41	4.19	3.78	3.38	3.07	2.81	2.38	2.08	1.62	1.31	0.66	0.43	0.26	1.64	158.3	5.04	2.01
.056	6.14	5.42	5.18	4.93	4.71	4.50	4.28	3.86	3.46	3.13	2.87	2.43	2.13	1.66	1.35	0.67	0.44	0.26	1.66	163.0	5.12	2.02
.058	6.26	5.53	5.28	5.03	4.80	4.59	4.37	3.94	3.54	3.24	2.94	2.49	2.17	1.70	1.39	0.69	0.46	0.27	1.69	167.8	5.21	2.04
.060	6.38	5.64	5.38	5.12	4.89	4.68	4.46	4.02	3.61	3.30	3.00	2.54	2.22	1.75	1.43	0.71	0.47	0.28	1.71	172.6	5.29	2.06
.062	6.51	5.75	5.48	5.22	4.98	4.77	4.54	4.09	3.69	3.36	3.06	2.60	2.27	1.79	1.46	0.73	0.48	0.29	1.74	177.4	5.38	2.07
.064	6.63	5.85	5.58	5.32	5.07	4.86	4.63	4.17	3.77	3.42	3.12	2.65	2.33	1.83	1.49	0.75	0.50	0.30	1.76	182.1	5.46	2.09
.066	6.75	5.96	5.68	5.42	5.16	4.94	4.72	4.25	3.84	3.48	3.18	2.71	2.37	1.87	1.52	0.77	0.51	0.30	1.78	186.9	5.55	2.11
.068	6.87	6.07	5.78	5.51	5.25	5.03	4.80	4.32	3.92	3.54	3.25	2.76	2.40	1.91	1.56	0.79	0.52	0.31	1.80	191.7	5.63	2.12
.070	6.99	6.17	5.88	5.61	5.34	5.12	4.89	4.40	3.99	3.60	3.31	2.82	2.44	1.95	1.59	0.81	0.54	0.32	1.83	196.4	5.72	2.14
.072	7.11	6.28	5.98	5.71	5.43	5.21	4.98	4.48	4.06	3.66	3.37	2.87	2.50	1.99	1.63	0.83	0.55	0.33	1.85	201.2	5.80	2.16
.074	7.23	6.39	6.08	5.81	5.52	5.30	5.06	4.55	4.14	3.71	3.43	2.93	2.56	2.03	1.66	0.85	0.56	0.33	1.87	206.0	5.89	2.17
.076	7.35	6.49	6.18	5.90	5.61	5.38	5.15	4.63	4.21	3.77	3.49	2.98	2.58	2.07	1.69	0.86	0.57	0.34	1.89	210.8	5.97	2.19
.078	7.47	6.60	6.28	6.00	5.70	5.47	5.24	4.70	4.28	3.83	3.55	3.04	2.63	2.10	1.73	0.89	0.59	0.35	1.91	215.5	6.05	2.20
.080	7.60	6.71	6.38	6.10	5.79	5.56	5.32	4.78	4.36	3.90	3.61	3.09	2.68	2.14	1.76	0.90	0.60	0.36	1.93	220.3	6.14	2.22

Table 6.7A.5 Values of ultimate axial stress, P_u/A_g, for circular column, f'_c = 4 ksi, f_{dy} = 72 ksi, γ = 0.45, 0.60, 0.75, 0.90



VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .45

P_g Steel Ratio	VALUES OF ECCENTRICITY RATIO $\delta e/D$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
.010	4.28	3.66	3.41	3.17	2.92	2.70	2.47	2.03	1.65	1.36	1.18	0.87	0.66	0.45	0.33	0.15	0.09	0.05	1.00	45.2	3.07	1.30
.012	4.38	3.74	3.48	3.23	2.97	2.75	2.52	2.07	1.68	1.42	1.21	0.92	0.72	0.49	0.37	0.16	0.10	0.06	1.00	46.4	3.13	1.27
.014	4.48	3.81	3.55	3.29	3.02	2.80	2.56	2.12	1.71	1.46	1.25	0.96	0.77	0.53	0.40	0.18	0.12	0.07	1.00	47.6	3.20	1.23
.016	4.58	3.89	3.61	3.35	3.07	2.85	2.61	2.17	1.76	1.51	1.31	1.00	0.81	0.56	0.43	0.19	0.13	0.07	1.00	48.8	3.26	1.20
.018	4.68	3.97	3.68	3.40	3.13	2.89	2.65	2.21	1.81	1.55	1.33	1.04	0.84	0.60	0.46	0.21	0.13	0.08	1.00	50.0	3.33	1.17
.020	4.77	4.04	3.75	3.46	3.18	2.94	2.70	2.26	1.87	1.58	1.37	1.07	0.87	0.62	0.48	0.22	0.14	0.08	1.00	51.2	3.39	1.14
.022	4.87	4.12	3.82	3.52	3.23	2.99	2.74	2.30	1.86	1.61	1.41	1.10	0.90	0.64	0.50	0.23	0.15	0.09	1.00	52.4	3.45	1.11
.024	4.97	4.19	3.88	3.58	3.28	3.04	2.79	2.34	1.90	1.66	1.44	1.14	0.93	0.67	0.52	0.24	0.16	0.09	1.00	53.6	3.52	1.07
.026	5.07	4.27	3.95	3.64	3.34	3.09	2.83	2.32	1.93	1.67	1.46	1.16	0.95	0.70	0.54	0.26	0.17	0.10	1.00	54.8	3.58	1.04
.028	5.17	4.35	4.02	3.70	3.39	3.14	2.88	2.36	1.97	1.68	1.50	1.18	0.98	0.72	0.56	0.26	0.17	0.10	1.00	56.0	3.65	1.01
.030	5.27	4.42	4.09	3.76	3.44	3.19	2.93	2.40	2.01	1.73	1.53	1.22	1.00	0.74	0.58	0.28	0.18	0.11	1.00	57.2	3.71	0.98
.032	5.37	4.50	4.15	3.81	3.50	3.24	2.97	2.44	2.05	1.78	1.56	1.24	1.02	0.76	0.60	0.28	0.19	0.11	1.00	58.4	3.77	0.95
.034	5.47	4.57	4.22	3.87	3.55	3.29	3.02	2.48	2.08	1.77	1.59	1.26	1.05	0.78	0.61	0.29	0.19	0.11	1.00	59.5	3.84	0.91
.036	5.57	4.65	4.29	3.93	3.60	3.34	3.06	2.51	2.12	1.80	1.61	1.29	1.07	0.80	0.63	0.30	0.20	0.12	1.00	60.7	3.90	0.88
.038	5.67	4.72	4.35	3.99	3.65	3.39	3.11	2.55	2.16	1.84	1.64	1.31	1.09	0.81	0.64	0.31	0.20	0.12	1.00	61.9	3.97	0.85
.040	5.77	4.79	4.42	4.05	3.71	3.44	3.15	2.59	2.20	1.87	1.66	1.34	1.11	0.83	0.66	0.32	0.21	0.12	1.00	63.1	4.03	0.82
.042	5.87	4.87	4.49	4.10	3.76	3.49	3.20	2.63	2.23	1.90	1.66	1.36	1.13	0.84	0.67	0.33	0.22	0.13	1.00	64.3	4.09	0.78
.044	5.97	4.94	4.55	4.16	3.81	3.54	3.25	2.67	2.27	1.94	1.70	1.38	1.15	0.86	0.69	0.34	0.22	0.13	1.00	65.5	4.16	0.75
.046	6.07	5.02	4.62	4.22	3.87	3.59	3.29	2.71	2.31	1.97	1.71	1.40	1.17	0.88	0.70	0.34	0.23	0.13	1.00	66.7	4.22	0.72
.048	6.17	5.09	4.69	4.27	3.92	3.64	3.34	2.75	2.35	2.01	1.74	1.43	1.19	0.89	0.71	0.35	0.23	0.14	1.00	67.9	4.29	0.69
.050	6.27	5.17	4.75	4.33	3.97	3.69	3.38	2.78	2.38	2.04	1.77	1.42	1.19	0.90	0.72	0.36	0.24	0.14	1.00	69.1	4.35	0.66
.052	6.37	5.24	4.82	4.39	4.03	3.74	3.43	2.82	2.37	2.08	1.80	1.44	1.21	0.92	0.73	0.37	0.24	0.14	1.00	70.3	4.42	0.62
.054	6.47	5.31	4.89	4.45	4.08	3.79	3.48	2.86	2.40	2.11	1.83	1.46	1.23	0.93	0.75	0.37	0.25	0.15	1.00	71.5	4.48	0.59
.056	6.56	5.39	4.95	4.50	4.13	3.83	3.52	2.90	2.44	2.10	1.86	1.48	1.25	0.94	0.76	0.38	0.25	0.15	1.00	72.7	4.54	0.56
.058	6.66	5.46	5.02	4.56	4.19	3.88	3.57	2.93	2.47	2.13	1.89	1.51	1.26	0.96	0.77	0.38	0.26	0.15	1.00	73.9	4.61	0.53
.060	6.76	5.53	5.08	4.62	4.24	3.93	3.61	2.97	2.51	2.16	1.92	1.53	1.28	0.98	0.78	0.39	0.26	0.16	1.00	75.1	4.67	0.50
.062	6.86	5.61	5.15	4.67	4.29	3.98	3.66	3.01	2.54	2.19	1.95	1.55	1.30	0.99	0.79	0.40	0.26	0.16	1.00	76.2	4.74	0.46
.064	6.96	5.68	5.22	4.73	4.35	4.03	3.70	3.05	2.57	2.22	1.98	1.57	1.32	1.00	0.80	0.40	0.27	0.16	1.00	77.4	4.80	0.43
.066	7.06	5.75	5.28	4.78	4.40	4.08	3.75	3.08	2.61	2.25	1.97	1.59	1.34	1.01	0.81	0.41	0.27	0.16	1.00	78.6	4.86	0.40
.068	7.16	5.83	5.35	4.84	4.45	4.13	3.80	3.12	2.64	2.28	2.00	1.61	1.36	1.02	0.83	0.42	0.28	0.17	1.01	79.8	4.93	0.37
.070	7.26	5.90	5.41	4.90	4.51	4.18	3.84	3.16	2.68	2.31	2.02	1.63	1.37	1.04	0.83	0.42	0.28	0.17	1.02	81.0	4.99	0.33
.072	7.36	5.97	5.48	4.95	4.56	4.23	3.89	3.19	2.71	2.34	2.05	1.65	1.39	1.06	0.84	0.43	0.29	0.17	1.02	82.2	5.06	0.30
.074	7.46	6.04	5.54	5.01	4.61	4.28	3.94	3.23	2.75	2.38	2.08	1.67	1.40	1.07	0.86	0.43	0.29	0.18	1.03	83.4	5.12	0.27
.076	7.56	6.12	5.61	5.06	4.67	4.33	3.98	3.27	2.78	2.41	2.11	1.69	1.42	1.09	0.87	0.44	0.29	0.18	1.04	84.6	5.18	0.24
.078	7.66	6.19	5.68	5.12	4.72	4.38	4.03	3.31	2.82	2.44	2.13	1.72	1.44	1.10	0.88	0.44	0.30	0.18	1.05	85.8	5.25	0.21
.080	7.76	6.26	5.74	5.18	4.77	4.43	4.07	3.34	2.85	2.47	2.16	1.74	1.46	1.11	0.89	0.45	0.30	0.18	1.05	87.0	5.31	0.17

VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6

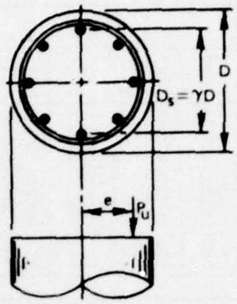
P_g Steel Ratio	VALUES OF ECCENTRICITY RATIO $\delta e/D$: 0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff. D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
.010	4.30	3.72	3.47	3.25	3.02	2.81	2.61	2.18	1.80	1.53	1.30	0.95	0.72	0.47	0.35	0.15	0.10	0.06	1.00	49.9	3.45	1.62
.012	4.40	3.80	3.55	3.33	3.09	2.88	2.68	2.24	1.89	1.59	1.35	1.02	0.79	0.53	0.39	0.17	0.11	0.06	1.00	52.0	3.52	1.61
.014	4.51	3.89	3.64	3.40	3.17	2.95	2.75	2.30	1.96	1.65	1.42	1.09	0.86	0.58	0.44	0.19	0.12	0.07	1.00	54.1	3.60	1.60
.016	4.61	3.98	3.72	3.48	3.24	3.02	2.82	2.36	1.98	1.69	1.48	1.13	0.91	0.63	0.48	0.21	0.13	0.08	1.00	56.2	3.67	1.59
.018	4.71	4.07	3.80	3.56	3.31	3.08	2.89	2.42	2.04	1.77	1.57	1.20	0.95	0.67	0.51	0.23	0.15	0.09	1.00	58.4	3.75	1.58
.020	4.82	4.15	3.88	3.63	3.39	3.15	2.95	2.47	2.10	1.84	1.61	1.26	1.00	0.72	0.55	0.25	0.16	0.09	1.00	60.5	3.82	1.57
.022	4.93	4.24	3.96	3.71	3.46	3.22	3.02	2.52	2.16	1.86	1.65	1.31	1.06	0.75	0.58	0.26	0.17	0.10	1.00	62.6	3.89	1.57
.024	5.03	4.33	4.04	3.79	3.53	3.28	3.09	2.57	2.22	1.91	1.68	1.34	1.09	0.78	0.60	0.28	0.18	0.10	1.00	64.7	3.97	1.56
.026	5.14	4.42	4.13	3.86	3.60	3.35	3.15	2.63	2.27	1.97	1.74	1.39	1.14	0.82	0.63	0.29	0.19	0.11	1.00	66.8	4.04	1.55
.028	5.24	4.51	4.21	3.94	3.68	3.41	3.22	2.70	2.33	2.02	1.77	1.44	1.19	0.85	0.66	0.31	0.20	0.12	1.00	69.0	4.12	1.54
.030	5.35	4.60	4.29	4.02	3.75	3.48	3.28	2.76	2.39	2.08	1.82	1.48	1.22	0.89	0.69	0.32	0.21	0.12	1.00	71.1	4.19	1.53
.032	5.46	4.68	4.37	4.09	3.82	3.54	3.35	2.82	2.44	2.13	1.87	1.52	1.26	0.92	0.72	0.34	0.22	0.13	1.00	73.2	4.27	1.52
.034	5.56	4.77	4.45	4.17	3.90	3.61	3.41	2.89	2.49	2.18	1.91	1.56	1.30	0.95	0.75	0.35	0.23	0.13	1.00	75.3	4.34	1.51
.036	5.67	4.86	4.54	4.25	3.97	3.67	3.48	2.95	2.55	2.24	1.96	1.61	1.33	0.98	0.77	0.36	0.24	0.14	1.00	77.4	4.41	1.50
.038	5.78	4.95	4.62	4.32	4.04	3.74	3.54	3.01	2.60	2.29	2.01	1.63	1.37	1.01	0.79	0.38	0.25	0.14	1.01	79.6	4.49	1.49
.040	5.88	5.04	4.70	4.40	4.11	3.81	3.60	3.08	2.65	2.34	2.06	1.66	1.41	1.04	0.82	0.39	0.25	0.15	1.02	81.7	4.56	1.48
.042	5.99	5.12	4.78	4.48	4.19	3.88	3.67	3.14	2.70	2.39	2.11	1.71	1.44	1.07	0.84	0.40	0.26	0.16	1.03	83.8	4.64	1.47
.044	6.10	5.21	4.87	4.55	4.26	3.95	3.73	3.20	2.75	2.40	2.12	1.72	1.47	1.10	0.87	0.42	0.27	0.16	1.05	85.9	4.71	1.47
.046	6.20	5.30	4.95	4.63	4.33	4.02	3.79	3.26	2.80	2.45	2.17	1.76	1.51	1.13	0.89	0.43	0.28	0.17	1.06	88.0	4.79	1.46
.048	6.31	5.39	5.03	4.70	4.41	4.09	3.86	3.32	2.89	2.50	2.21	1.80	1.53	1.15	0.91	0.44	0.29	0.17	1.07	90.2	4.86	1.45
.050	6.42	5.48	5.11	4.78	4.48	4.15	3.92	3.38	2.93	2.54	2.26	1.84	1.57	1.18	0.94	0.45	0.30	0.18	1.08	92.3	4.94	1.44
.052	6.52	5.57	5.20	4.86	4.55	4.22	3.98	3.45	2.97	2.59	2.30	1.89	1.60	1.21	0.96	0.46	0.30	0.18	1.10	94.4	5.01	1.43
.054	6.63	5.65	5.28	4.93	4.62	4.29	4.05	3.51	3.02	2.64	2.35	1.93	1.63	1.23	0.98	0.48	0.31	0.19	1.11	96.5	5.08	1.42
.056	6.74	5.74	5.36	5.01	4.70	4.36	4.11	3.57	3.06	2.69	2.39	1.94	1.64	1.26	1.00	0.49	0.32	0.19	1.12	98.6	5.16	1.41
.058	6.85	5.83	5.44	5.09	4.77	4.43	4.17	3.63	3.10	2.73	2.44	1.97	1.66	1.28	1.02	0.50	0.33	0.19	1.13	100.8	5.23	1.40
.060	6.95	5.92	5.53	5.16	4.84	4.50	4.23	3.69	3.14	2.78	2.48	2.01	1.70	1.31	1.05	0.51	0.34	0.20	1.14	102.9	5.31	1.39
.062	7.06	6.01	5.61	5.24	4.91	4.57	4.29	3.65	3.18	2.83	2.53	2.05	1.73	1.32	1.06	0.52	0.34	0.20	1.16	105.0	5.38	1.38
.064	7.17	6.09	5.69	5.31	4.99	4.63	4.36	3.71	3.23	2.87	2.57	2.09	1.76	1.34	1.08	0.53	0.35	0.21	1.17	107.1	5.46	1.37
.066	7.28	6.18	5.77	5.39	5.06	4.70	4.42	3.76	3.27	2.92	2.61	2.12	1.80	1.37	1.10	0.54	0.36	0.21	1.18	109.2	5.53	1.37
.068	7.38	6.27	5.86	5.47	5.13	4.77	4.48	3.82	3.31	2.96	2.66	2.16	1.83	1.39	1.12	0.55	0.37	0.22	1.19	111.4	5.60	1.36
.070	7.49	6.36	5.94	5.54	5.20	4.84	4.54	3.88	3.36	3.01	2.67	2.20	1.84	1.41	1.14	0.57	0.37	0.22	1.20	113.5	5.68	1.35
.072	7.60	6.45	6.02	5.62	5.28	4.91	4.60	3.93	3.42	3.05	2.71	2.24	1.87	1.44	1.16	0.58	0.38	0.23	1.21	115.6	5.75	1.34
.074	7.71	6.54	6.10	5.69	5.35	4.98	4.66	3.99	3.47	3.10	2.75	2.28	1.91	1.46	1.18	0.59	0.39	0.23	1.22	117.7	5.83	1.33
.076	7.81	6.62	6.19	5.77	5.42	5.05	4.73	4.04	3.53	3.14	2.80	2.29	1.94	1.49	1.20	0.60	0.40	0.24	1.24	119.9	5.90	1.32
.078	7.92	6.71	6.27	5.85	5.49	5.11	4.79	4.10	3.59	3.19	2.84	2.32	1.97	1.51	1.22	0.61	0.40	0.24	1.25	122.0	5.98	1.31
.080	8.03	6.80	6.35	5.92	5.57	5.18	4.85	4.16	3.64	3.23	2.88	2.36	2.00	1.53	1.24	0.62	0.41	0.25	1.26	124.1	6.05	1.30

L/D_e	VALUES OF MOMENT MULTIPLIERS δ																					
	VALUES OF ULTIMATE STRESS P_u/A_g IN KSI																					
	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03
3.0	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06
4.0	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
5.0	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.08	1.10	1.11	1.13	1.15	1.16	1.18	1.20
6.0	1.01	1.01	1.02	1.03	1.04	1.05	1.05	1.06	1.07	1.08	1.09	1.10	1.10	1.11	1.12	1.15	1.17	1.20	1.22	1.25	1.28	1.31
7.0	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.09	1.10	1.11	1.12	1.14	1.15	1.16	1.18	1.21	1.25	1.29	1.33	1.38	1.42	1.48
8.0	1.01	1.03	1.04	1.05	1.07	1.08	1.10	1.12	1.13	1.15	1.17	1.18	1.20	1.22	1.24	1.29	1.35	1.41	1.48	1.55	1.64	1.73
9.0	1.02	1.03	1.05	1.07	1.09	1.11	1.13	1.15	1.17	1.20	1.22	1.25	1.27	1.30	1.33	1.40	1.49	1.59	1.70	1.82	1.97	2.14
10.0	1.02	1.04	1.06	1.09	1.11	1.14	1.17	1.19	1.22	1.25	1.29	1.32	1.36	1.40	1.44	1.55	1.68	1.84	2.03	2.26	2.55	2.93
11.0	1.03	1.05	1.08	1.11	1.14	1.17	1.21	1.24	1.28	1.32	1.37	1.42	1.47	1.52	1.58	1.75	1.96	2.23	2.58	3.07	3.78	4.92
12.0	1.03	1.06	1.10	1.13	1.17	1.21	1.26	1.30	1.36	1.41	1.47	1.54	1.61	1.69	1.78	2.04	2.40	2.91	3.70	5.06	8.03	
13.0	1.04	1.07	1.11	1.16	1.21	1.26	1.32	1.38	1.45	1.52	1.60	1.70	1.80	1.92	2.06	2.50	3.17	4.36	6.95			
14.0	1.04	1.09	1.14	1.19	1.25	1.31	1.39	1.47	1.56	1.66	1.78	1.91	2.07	2.25	2.47	3.28	4.86	9.40				
15.0	1.05	1.10	1.16	1.22	1.30	1.38	1.47	1.57	1.70	1.84	2.01	2.21	2.46	2.76	3.16	4.95						
16.0	1.05	1.12	1.18	1.26	1.35	1.45	1.57	1.71	1.88	2.08	2.33	2.65	3.07	3.65	4.51							
17.0	1.06	1.13	1.21	1.31	1.41	1.54	1.69	1.88	2.11	2.41	2.81	3.36	4.19	5.55	8.23							
18.0	1.07	1.15	1.25	1.36	1.49	1.65	1.85	2.11	2.44	2.91	3.60	4.71	6.83									

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI Y = .75																		Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO δe/D																					
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00				
.010	4.32	3.77	3.54	3.32	3.11	2.90	2.73	2.29	1.96	1.66	1.43	1.04	0.81	0.53	0.39	0.16	0.10	0.06	1.00	55.8	3.79	1.91
.012	4.44	3.86	3.63	3.41	3.20	2.99	2.81	2.37	2.05	1.74	1.53	1.13	0.88	0.59	0.43	0.19	0.12	0.07	1.00	59.2	3.87	1.91
.014	4.55	3.96	3.73	3.50	3.29	3.07	2.89	2.46	2.14	1.84	1.60	1.21	0.96	0.66	0.49	0.21	0.13	0.08	1.00	62.5	3.95	1.92
.016	4.66	4.06	3.82	3.59	3.38	3.16	2.97	2.54	2.22	1.93	1.67	1.29	1.03	0.71	0.53	0.23	0.15	0.09	1.00	65.8	4.03	1.93
.018	4.77	4.15	3.92	3.67	3.47	3.25	3.05	2.63	2.29	2.01	1.74	1.37	1.09	0.77	0.58	0.25	0.16	0.09	1.00	69.1	4.11	1.93
.020	4.88	4.25	4.01	3.76	3.55	3.33	3.12	2.71	2.36	2.04	1.83	1.44	1.16	0.82	0.63	0.28	0.18	0.10	1.00	72.4	4.19	1.94
.022	4.99	4.34	4.10	3.85	3.64	3.42	3.20	2.79	2.42	2.11	1.91	1.51	1.23	0.87	0.67	0.30	0.19	0.11	1.00	75.7	4.26	1.95
.024	5.10	4.44	4.20	3.94	3.72	3.50	3.27	2.87	2.48	2.18	1.94	1.57	1.29	0.91	0.71	0.32	0.20	0.12	1.00	79.0	4.34	1.95
.026	5.21	4.53	4.29	4.03	3.81	3.59	3.36	2.95	2.53	2.25	2.00	1.64	1.34	0.96	0.75	0.34	0.22	0.13	1.02	82.3	4.42	1.96
.028	5.32	4.63	4.38	4.11	3.89	3.67	3.44	3.02	2.60	2.31	2.06	1.67	1.39	1.02	0.79	0.36	0.23	0.13	1.04	85.7	4.50	1.97
.030	5.43	4.72	4.47	4.20	3.97	3.75	3.52	3.10	2.68	2.38	2.12	1.74	1.45	1.05	0.82	0.38	0.24	0.14	1.06	89.0	4.58	1.97
.032	5.54	4.82	4.57	4.29	4.06	3.83	3.60	3.17	2.75	2.44	2.19	1.81	1.50	1.10	0.85	0.40	0.26	0.15	1.08	92.3	4.66	1.98
.034	5.65	4.92	4.66	4.38	4.14	3.92	3.68	3.24	2.83	2.50	2.25	1.84	1.56	1.15	0.89	0.41	0.27	0.16	1.10	95.6	4.74	1.99
.036	5.76	5.02	4.75	4.47	4.27	4.00	3.76	3.31	2.90	2.59	2.31	1.89	1.60	1.18	0.93	0.43	0.28	0.16	1.12	98.9	4.82	1.99
.038	5.87	5.12	4.84	4.56	4.30	4.08	3.84	3.38	2.98	2.64	2.36	1.94	1.65	1.22	0.96	0.45	0.29	0.17	1.14	102.2	4.90	2.00
040	5.98	5.21	4.93	4.65	4.38	4.16	3.92	3.45	3.05	2.69	2.42	1.99	1.69	1.27	0.99	0.47	0.31	0.18	1.16	105.5	4.98	2.01
.042	6.10	5.31	5.03	4.74	4.47	4.24	4.00	3.52	3.12	2.74	2.48	2.04	1.75	1.30	1.03	0.49	0.32	0.19	1.18	108.9	5.06	2.01
.044	6.21	5.41	5.12	4.83	4.55	4.32	4.08	3.59	3.12	2.79	2.53	2.10	1.77	1.34	1.06	0.50	0.33	0.19	1.20	112.2	5.14	2.02
.046	6.32	5.51	5.21	4.92	4.63	4.40	4.16	3.66	3.18	2.83	2.59	2.15	1.82	1.38	1.09	0.52	0.34	0.20	1.21	115.5	5.22	2.03
.048	6.43	5.61	5.30	5.01	4.71	4.48	4.24	3.72	3.25	2.90	2.64	2.20	1.86	1.42	1.12	0.54	0.35	0.21	1.23	118.8	5.30	2.03
.050	6.54	5.70	5.39	5.09	4.79	4.56	4.32	3.79	3.31	2.97	2.69	2.25	1.91	1.46	1.16	0.55	0.36	0.21	1.25	122.1	5.38	2.04
052	6.65	5.80	5.48	5.18	4.87	4.64	4.39	3.85	3.38	3.04	2.75	2.27	1.95	1.49	1.19	0.57	0.37	0.22	1.26	125.4	5.46	2.05
.054	6.76	5.90	5.57	5.27	4.95	4.72	4.47	3.92	3.44	3.11	2.80	2.32	1.99	1.53	1.22	0.59	0.39	0.23	1.28	128.7	5.54	2.05
.056	6.87	6.00	5.67	5.36	5.03	4.80	4.55	3.98	3.50	3.17	2.85	2.37	2.04	1.56	1.25	0.61	0.40	0.23	1.30	132.0	5.62	2.06
.058	6.98	6.10	5.76	5.45	5.12	4.87	4.63	4.05	3.57	3.24	2.90	2.42	2.08	1.60	1.28	0.62	0.41	0.24	1.31	135.4	5.70	2.07
.060	7.09	6.20	5.85	5.54	5.20	4.95	4.70	4.11	3.63	3.24	2.97	2.47	2.13	1.62	1.31	0.64	0.42	0.25	1.33	138.7	5.78	2.07
.062	7.20	6.29	5.94	5.62	5.28	5.03	4.78	4.18	3.69	3.29	3.02	2.51	2.15	1.67	1.34	0.65	0.43	0.25	1.34	142.0	5.86	2.08
.064	7.31	6.39	6.03	5.71	5.37	5.11	4.86	4.24	3.76	3.35	3.06	2.56	2.19	1.68	1.37	0.67	0.44	0.26	1.36	145.3	5.93	2.09
.066	7.43	6.49	6.12	5.80	5.45	5.19	4.93	4.30	3.82	3.41	3.10	2.61	2.23	1.72	1.40	0.69	0.45	0.27	1.38	148.6	6.01	2.09
.068	7.55	6.59	6.21	5.89	5.54	5.27	5.01	4.37	3.88	3.47	3.14	2.65	2.27	1.76	1.42	0.70	0.46	0.27	1.39	151.9	6.09	2.10
070	7.66	6.69	6.30	5.98	5.62	5.34	5.09	4.43	3.94	3.53	3.18	2.70	2.31	1.79	1.45	0.72	0.47	0.28	1.41	155.2	6.17	2.10
.072	7.78	6.78	6.39	6.06	5.71	5.42	5.16	4.49	4.01	3.58	3.25	2.75	2.36	1.83	1.48	0.73	0.48	0.29	1.42	158.6	6.25	2.11
.074	7.90	6.88	6.48	6.15	5.79	5.50	5.24	4.55	4.07	3.64	3.31	2.79	2.40	1.86	1.51	0.75	0.49	0.29	1.44	161.9	6.33	2.12
.076	8.02	6.98	6.57	6.24	5.88	5.58	5.32	4.62	4.13	3.70	3.37	2.84	2.44	1.90	1.54	0.76	0.50	0.30	1.45	165.2	6.41	2.12
.078	8.13	7.08	6.66	6.33	5.96	5.65	5.39	4.68	4.19	3.75	3.43	2.89	2.48	1.93	1.57	0.78	0.51	0.31	1.46	168.5	6.49	2.13
.080	8.25	7.17	6.75	6.41	6.05	5.73	5.47	4.75	4.25	3.81	3.49	2.93	2.52	1.95	1.59	0.79	0.52	0.31	1.48	171.8	6.57	2.14

P_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI Y = .9																		Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO δe/D																					
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00				
.010	4.36	3.82	3.61	3.39	3.20	3.01	2.82	2.42	2.08	1.78	1.54	1.14	0.88	0.58	0.42	0.18	0.11	0.06	1.00	63.1	4.09	2.16
.012	4.48	3.92	3.71	3.49	3.30	3.11	2.91	2.53	2.18	1.89	1.64	1.26	0.98	0.65	0.49	0.20	0.13	0.07	1.00	67.9	4.17	2.18
.014	4.59	4.02	3.82	3.60	3.40	3.21	3.01	2.63	2.27	1.99	1.73	1.34	1.08	0.73	0.54	0.23	0.15	0.08	1.00	72.7	4.26	2.19
.016	4.71	4.13	3.92	3.70	3.50	3.31	3.11	2.73	2.35	2.09	1.83	1.43	1.16	0.80	0.60	0.26	0.16	0.09	1.00	77.4	4.34	2.21
.018	4.83	4.24	4.02	3.80	3.59	3.40	3.21	2.82	2.45	2.17	1.93	1.52	1.22	0.86	0.65	0.29	0.18	0.11	1.02	82.2	4.42	2.22
.020	4.94	4.34	4.12	3.90	3.68	3.50	3.31	2.91	2.55	2.25	2.02	1.62	1.31	0.93	0.70	0.31	0.20	0.12	1.05	87.0	4.51	2.24
.022	5.06	4.45	4.22	4.00	3.77	3.59	[illegible]	2.99	2.65	2.33	2.10	1.67	1.38	0.99	0.76	0.34	0.22	0.12	1.08	91.8	4.59	2.25
.024	5.17	4.55	4.32	4.10	3.87	3.68	[illegible]	3.07	2.73	2.40	2.17	1.75	1.45	1.04	0.81	0.36	0.23	0.13	1.11	96.5	4.67	2.27
.026	5.28	4.66	4.42	4.20	3.96	3.77	3.59	3.15	2.82	2.47	2.25	1.84	1.52	1.10	0.85	0.39	0.25	0.14	1.14	101.3	4.76	2.28
028	5.40	4.77	4.52	4.30	4.06	3.86	3.68	3.22	2.90	2.56	2.32	1.92	1.58	1.16	0.90	0.41	0.26	0.15	1.16	106.1	4.84	2.30
030	5.51	4.87	4.61	4.39	4.16	3.95	3.77	3.30	2.98	2.65	2.39	1.99	1.65	1.20	0.94	0.43	0.28	0.16	1.19	110.8	4.92	2.31
.032	5.62	4.98	4.71	4.49	4.25	4.04	3.85	3.37	3.06	2.73	2.45	2.02	1.70	1.26	0.98	0.46	0.29	0.17	1.21	115.6	5.00	2.33
.034	5.73	5.08	4.81	4.59	4.35	4.12	3.94	3.45	3.14	2.76	2.51	2.09	1.77	1.31	1.02	0.48	0.31	0.18	1.24	120.4	5.09	2.35
.036	5.85	5.18	4.91	4.68	4.45	4.21	4.03	3.54	3.21	2.84	2.57	2.15	1.81	1.36	1.07	0.50	0.32	0.19	1.26	125.2	5.17	2.36
.038	5.96	5.29	5.01	4.78	4.54	4.29	4.11	3.63	3.29	2.91	2.64	2.21	1.87	1.41	1.11	0.52	0.34	0.20	1.29	129.9	5.25	2.38
.040	6.08	5.39	5.11	4.87	4.63	4.38	4.20	3.71	3.36	2.98	2.72	2.27	1.93	1.46	1.15	0.55	0.35	0.21	1.31	134.7	5.34	2.39
.042	6.20	5.50	5.22	4.97	4.73	4.47	4.28	3.80	3.43	3.05	2.80	2.33	1.99	1.51	1.19	0.57	0.37	0.22	1.33	139.5	5.42	2.41
.044	6.33	5.60	5.32	5.06	4.82	4.57	4.36	3.88	3.50	3.12	2.83	2.39	2.04	1.55	1.23	0.59	0.38	0.22	1.36	144.2	5.50	2.42
.046	6.45	5.70	5.42	5.16	4.91	4.66	4.45	3.97	3.57	3.19	2.89	2.44	2.10	1.60	1.27	0.61	0.40	0.23	1.38	149.0	5.59	2.44
.048	6.57	5.80	5.52	5.25	5.01	4.75	4.53	4.05	3.63	3.26	2.96	2.50	2.15	1.64	1.31	0.63	0.41	0.24	1.40	153.8	5.67	2.45
.050	6.69	5.91	5.62	5.34	5.10	4.84	4.61	4.13	3.70	3.33	3.02	2.59	2.21	1.69	1.35	0.65	0.42	0.25	1.42	158.6	5.75	2.47
.052	6.81	6.01	5.72	5.43	5.19	4.93	4.69	4.21	3.76	3.39	3.08	2.64	2.26	1.72	1.39	0.67	0.44	0.26	1.44	163.3	5.83	2.48
.054	6.93	6.11	5.82	5.53	5.28	5.02	4.77	4.29	3.83	3.46	3.15	2.69	2.31	1.77	1.42	0.69	0.45	0.27	1.46	168.1	5.92	2.50
.056	7.04	6.21	5.92	5.62	5.37	5.11	4.85	4.37	3.89	3.53	3.21	2.74	2.36	1.81	1.46	0.71	0.47	0.27	1.48	172.9	6.00	2.52
.058	7.16	6.31	6.02	5.71	5.47	5.20	4.93	4.45	3.96	3.60	3.28	2.78	2.41	1.86	1.50	0.73	0.48	0.28	1.50	177.6	6.08	2.53
060	7.27	6.42	6.12	5.80	5.56	5.29	5.01	4.53	4.02	3.66	3.34	2.83	2.46	1.90	1.54	0.75	0.49	0.29	1.52	182.4	6.17	2.55
.062	7.38	6.52	6.22	5.90	5.65	5.38	5.10	4.61	4.09	3.73	3.40	2.88	2.51	1.95	1.58	0.77	0.51	0.30	1.54	187.2	6.25	2.56
.064	7.49	6.62	6.32	5.99	5.74	5.47	5.19	4.69	4.17	3.80	3.47	2.95	2.56	1.99	1.61	0.79	0.52	0.31	1.56	192.0	6.33	2.58
066	7.60	6.72	6.42	6.09	5.83	5.56	5.28	4.77	4.24	3.86	3.53	3.02	2.61	2.04	1.64	0.81	0.53	0.32	1.58	196.7	6.41	2.59
.068	7.72	6.82	6.52	6.19	5.92	5.65	5.37	4.85	4.32	3.93	3.59	3.04	2.65	2.08	1.67	0.83	0.55	0.32	1.60	201.5	6.50	2.61
.070	7.83	6.92	6.62	6.28	6.01	5.74	5.45	4.93	4.40	3.99	3.66	3.09	2.70	2.12	1.70	0.85	0.56	0.33	1.62	206.3	6.58	2.62
.072	7.96	7.03	6.72	6.38	6.10	5.83	5.54	5.00	4.47	4.06	3.72	3.14	2.75	2.15	1.74	0.87	0.57	0.34	1.64	211.0	6.66	2.64
.074	8.08	7.13	6.82	6.48	6.19	5.92	5.63	5.08	4.55	4.12	3.78	3.20	2.80	2.19	1.78	0.89	0.59	0.35	1.66	215.8	6.75	2.65
.076	8.20	7.24	6.92	6.58	6.28	6.00	5.71	5.16	4.63	4.18	3.84	3.25	2.84	2.23	1.81	0.91	0.60	0.36	1.68	220.6	6.83	2.67
.078	8.32	7.34	7.01	6.67	6.37	6.09	5.80	5.23	4.70	4.30	3.90	3.31	2.89	2.27	1.85	0.93	0.61	0.36	1.69	225.4	6.91	2.68
080	8.44	7.45	7.11	6.77	6.46	6.18	5.89	5.31	4.78	4.36	3.96	3.36	2.93	2.31	1.89	0.95	0.62	0.37	1.71	230.1	7.00	2.70

Table 6.7A.6 Values of ultimate axial stress, P_u/A_g, for circular column, f'_c = 5 ksi, f_{dy} = 72 ksi, γ = 0.45, 0.60, 0.75, 0.90



p_g Steel Ratio	VALUES OF ULTIMATF AXIAL STRESS P_u/A_g IN KSI γ = .45																		Eff. D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO 6e/D																					
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00				
.010	5.23	4.49	4.19	3.88	3.59	3.30	3.03	2.45	1.95	1.61	1.37	0.98	0.75	0.49	0.36	0.16	0.10	0.06	1.00	55.1	3.51	1.52
.012	5.33	4.56	4.26	3.94	3.64	3.34	3.08	2.49	1.99	1.66	1.40	1.05	0.81	0.54	0.40	0.17	0.11	0.07	1.00	56.2	3.57	1.49
.014	5.43	4.64	4.32	4.00	3.69	3.39	3.12	2.53	2.05	1.71	1.45	1.10	0.86	0.59	0.44	0.19	0.12	0.07	1.00	57.4	3.64	1.45
.016	5.53	4.72	4.39	4.06	3.74	3.44	3.17	2.58	2.10	[illegible]	1.51	1.13	0.91	0.63	0.47	0.21	0.13	0.08	1.00	58.6	3.70	1.42
.018	5.63	4.80	4.46	4.13	3.80	3.48	3.21	2.62	2.15	1.80	1.56	1.18	0.95	0.66	0.50	0.23	0.14	0.08	1.00	59.8	3.76	1.39
.020	5.74	4.88	4.53	4.19	3.85	3.53	3.25	2.66	2.21	1.84	1.57	1.23	0.99	0.70	0.53	0.24	0.15	0.09	1.00	61.0	3.83	1.36
.022	5.84	4.95	4.59	4.25	3.90	3.58	3.30	2.70	2.26	1.90	1.61	1.27	1.02	0.72	0.55	0.25	0.16	0.10	1.00	62.2	3.89	1.32
.024	5.94	5.03	4.66	4.30	3.95	3.63	3.34	2.74	2.23	1.92	1.65	1.29	1.06	0.75	0.58	0.27	0.17	0.10	1.00	63.4	3.95	1.29
.026	6.04	5.11	4.73	4.36	4.00	3.68	3.39	2.78	2.26	1.93	1.69	1.33	1.08	0.77	0.60	0.28	0.18	0.11	1.00	64.6	4.02	1.26
.028	6.14	5.19	4.79	4.42	4.05	3.72	3.43	2.82	2.30	1.94	1.73	1.35	1.11	0.80	0.62	0.29	0.19	0.11	1.00	65.8	4.08	1.23
.030	6.24	5.26	4.86	4.48	4.10	3.77	3.48	2.86	2.34	2.00	1.76	1.38	1.13	0.82	0.64	0.30	0.20	0.12	1.00	67.0	4.14	1.19
.032	6.34	5.34	4.93	4.54	4.15	3.82	3.52	2.90	2.38	2.05	1.79	1.40	1.16	0.85	0.66	0.31	0.20	0.12	1.00	68.2	4.21	1.16
.034	6.44	5.42	4.99	4.60	4.20	3.87	3.57	2.93	2.41	2.04	1.82	1.44	1.18	0.87	0.68	0.32	0.21	0.12	1.00	69.4	4.27	1.13
.036	6.54	5.49	5.06	4.66	4.25	3.92	3.61	2.97	2.45	2.07	1.85	1.46	1.20	0.89	0.70	0.33	0.22	0.13	1.00	70.6	4.33	1.10
.038	6.64	5.57	5.12	4.72	4.30	3.96	3.66	3.01	2.49	2.11	1.87	1.48	1.23	0.91	0.72	0.34	0.22	0.13	1.00	71.8	4.40	1.07
.040	6.74	5.65	5.18	4.78	4.35	4.01	3.70	3.05	2.53	2.14	1.91	1.51	1.25	0.93	0.73	0.35	0.23	0.14	1.00	72.9	4.46	1.03
042	6.84	5.72	5.25	4.84	4.40	4.06	3.75	3.08	2.56	2.17	1.91	1.53	1.27	0.95	0.75	0.36	0.24	0.14	1.00	74.1	4.52	1.00
.044	6.94	5.80	5.31	4.89	4.45	4.11	3.79	3.12	2.60	2.21	1.92	1.56	1.29	0.96	0.76	0.37	0.24	0.14	1.00	75.3	4.59	0.97
.046	7.04	5.87	5.38	4.95	4.49	4.16	3.84	3.16	2.64	2.24	1.96	1.58	1.31	0.98	0.78	0.38	0.25	0.15	1.00	76.5	4.65	0.94
.048	7.14	5.95	5.44	5.01	4.54	4.21	3.88	3.19	2.67	2.28	2.02	1.60	1.33	1.00	0.79	0.38	0.25	0.15	1.00	77.7	4.71	0.90
.050	7.24	6.02	5.50	5.07	4.59	4.25	3.93	3.23	2.71	2.31	2.00	1.63	1.35	1.01	0.81	0.39	0.26	0.15	1.00	78.9	4.78	0.87
.052	7.34	6.10	5.57	5.13	4.64	4.30	3.97	3.26	2.75	2.35	2.03	1.65	1.37	1.03	0.82	0.40	0.26	0.16	1.00	80.1	4.84	0.84
.054	7.44	6.18	5.64	5.18	4.69	4.35	4.02	3.30	2.78	2.38	2.05	1.67	1.39	1.04	0.83	0.41	0.27	0.16	1.00	81.3	4.90	0.81
.056	7.54	6.25	5.70	5.24	4.73	4.40	4.06	3.34	2.82	2.41	2.08	1.70	1.41	1.06	0.85	0.42	0.28	0.16	1.00	82.5	4.97	0.77
.058	7.64	6.33	5.77	5.30	4.78	4.45	4.11	3.37	2.80	2.45	2.11	1.69	1.41	1.07	0.85	0.42	0.28	0.17	1.00	83.7	5.03	0.74
060	7.74	6.40	5.84	5.36	4.83	4.50	4.15	3.41	2.83	2.43	2.14	1.71	1.43	1.08	0.86	0.43	0.28	0.17	1.00	84.9	5.09	0.71
.062	7.84	6.47	5.90	5.41	4.88	4.54	4.20	3.44	2.87	2.46	2.18	1.73	1.45	1.09	0.87	0.44	0.29	0.17	1.00	86.1	5.16	0.68
.064	7.94	6.55	5.97	5.47	4.93	4.59	4.24	3.48	2.90	2.49	2.21	1.75	1.47	1.11	0.89	0.44	0.29	0.18	1.00	87.3	5.22	0.64
.066	8.04	6.62	6.03	5.53	4.98	4.64	4.29	3.51	2.93	2.52	2.24	1.78	1.48	1.13	0.90	0.45	0.30	0.18	1.00	88.5	5.28	0.61
.068	8.14	6.70	6.10	5.58	5.03	4.69	4.33	3.55	2.97	2.55	2.27	1.80	1.50	1.14	0.91	0.46	0.30	0.18	1.00	89.6	5.35	0.58
070	8.24	6.77	6.16	5.64	5.08	4.74	4.38	3.58	3.00	2.58	2.30	1.82	1.52	1.16	0.92	0.46	0.31	0.18	1.00	90.8	5.41	0.55
.072	8.34	6.85	6.23	5.70	5.14	4.79	4.42	3.62	3.04	2.61	2.28	1.84	1.54	1.17	0.93	0.47	0.31	0.19	1.00	92.0	5.47	0.51
.074	8.44	6.92	6.30	5.75	5.19	4.84	4.47	3.65	3.07	2.65	2.31	1.85	1.56	1.18	0.94	0.47	0.32	0.19	1.00	93.2	5.54	0.48
.076	8.54	6.99	6.36	5.81	5.24	4.89	4.51	3.69	3.10	2.68	2.34	1.89	1.58	1.19	0.96	0.48	0.32	0.19	1.00	94.4	5.60	0.45
.078	8.64	7.07	6.43	5.87	5.29	4.93	4.56	3.72	3.14	2.71	2.36	1.89	1.59	1.21	0.96	0.49	0.33	0.19	1.00	95.6	5.66	0.42
.080	8.74	7.14	6.49	5.92	5.34	4.98	4.60	3.76	3.17	2.74	2.39	1.92	1.61	1.22	0.98	0.49	0.33	0.20	1.00	96.8	5.73	0.38

p_g Steel Ratio	VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI γ = .6																		Eff. D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO 6e/D																					
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00				
010	5.25	4.52	4.24	3.95	3.68	3.40	3.16	2.59	2.14	1.78	1.49	1.07	0.81	0.52	0.38	0.16	0.10	0.06	1.00	59.7	3.96	1.87
.012	5.36	4.61	4.32	4.02	3.75	3.47	3.22	2.65	2.22	1.85	1.59	1.15	0.88	0.58	0.43	0.18	0.12	0.07	1.00	61.8	4.03	1.86
.014	5.46	4.70	4.41	4.10	3.82	3.54	3.29	2.71	2.30	1.91	1.67	1.21	0.94	0.64	0.47	0.20	0.13	0.07	1.00	63.9	4.10	1.85
.016	5.57	4.78	4.49	4.17	3.90	3.61	3.36	2.76	2.37	1.96	1.73	1.27	1.01	0.68	0.51	0.22	0.14	0.08	1.00	66.1	4.18	1.84
.018	5.67	4.87	4.57	4.25	3.97	3.67	3.42	2.82	2.44	2.04	1.79	1.34	1.07	0.73	0.55	0.24	0.15	0.09	1.00	68.2	4.25	1.83
.020	5.78	4.96	4.65	4.32	4.04	3.74	3.48	2.88	2.44	2.12	1.84	1.41	1.11	0.78	0.59	0.26	0.17	0.10	1.00	70.3	4.32	1.82
.022	5.88	5.05	4.73	4.40	4.11	3.81	3.55	2.95	2.50	2.13	1.88	1.47	1.17	0.82	0.63	0.28	0.18	0.10	1.00	72.4	4.40	1.81
024	5.99	5.13	4.81	4.47	4.18	3.88	3.61	3.01	2.56	2.19	1.92	1.53	1.22	0.86	0.66	0.30	0.19	0.11	1.00	74.5	4.47	1.80
.026	6.09	5.22	4.89	4.55	4.25	3.94	3.67	3.08	2.61	2.24	1.96	1.58	1.26	0.89	0.69	0.31	0.20	0.12	1.00	76.7	4.54	1.79
.028	6.20	5.31	4.97	4.62	4.32	4.01	3.74	3.14	2.67	2.30	2.04	1.61	1.31	0.93	0.72	0.33	0.21	0.12	1.00	78.8	4.62	1.78
.030	6.30	5.39	5.06	4.70	4.39	4.08	3.80	3.20	2.72	2.35	2.05	1.65	1.36	0.97	0.74	0.34	0.22	0.13	1.00	80.9	4.69	1.77
.032	6.41	5.48	5.14	4.77	4.47	4.15	3.86	3.27	2.78	2.41	2.10	1.70	1.40	1.00	0.78	0.36	0.23	0.14	1.00	83.0	4.76	1.77
034	6.51	5.57	5.22	4.84	4.54	4.21	3.93	3.33	2.83	2.46	2.15	1.74	1.43	1.04	0.80	0.37	0.24	0.14	1.00	85.1	4.84	1.76
.036	6.62	5.65	5.30	4.92	4.61	4.28	3.99	3.39	2.88	2.52	2.20	1.78	1.47	1.07	0.83	0.39	0.25	0.15	1.00	87.3	4.91	1.75
.038	6.72	5.74	5.38	4.99	4.68	4.35	4.05	3.45	2.94	2.57	2.25	1.83	1.51	1.10	0.86	0.40	0.26	0.15	1.00	89.4	4.98	1.74
.040	6.83	5.83	5.46	5.07	4.75	4.42	4.11	3.51	3.04	2.62	2.30	1.86	1.55	1.13	0.88	0.41	0.27	0.16	1.00	91.5	5.06	1.73
.042	6.93	5.91	5.54	5.14	4.82	4.48	4.17	3.57	3.09	2.67	2.35	1.90	1.58	1.17	0.91	0.43	0.28	0.16	1.00	93.6	5.13	1.72
.044	7.04	6.00	5.62	5.22	4.89	4.55	4.23	3.64	3.13	2.72	2.40	1.91	1.62	1.19	0.94	0.44	0.29	0.17	1.00	95.7	5.20	1.71
046	7.14	6.09	5.70	5.29	4.96	4.62	4.30	3.70	3.18	2.78	2.45	1.98	1.65	1.23	0.96	0.46	0.30	0.18	1.00	97.9	5.28	1.70
.048	7.25	6.18	5.79	5.37	5.03	4.69	4.36	3.76	3.22	2.83	2.50	1.98	1.69	1.26	0.99	0.47	0.31	0.18	1.01	100.0	5.35	1.69
.050	7.36	6.26	5.87	5.44	5.11	4.75	4.42	3.82	3.26	2.87	2.50	2.02	1.72	1.28	1.01	0.48	0.31	0.19	1.02	102.1	5.42	1.68
.052	7.46	6.35	5.95	5.52	5.18	4.82	4.48	3.88	3.31	2.88	2.54	2.06	1.75	1.31	1.03	0.49	0.32	0.19	1.03	104.2	5.50	1.67
.054	7.57	6.44	6.03	5.59	5.25	4.89	4.54	3.93	3.35	2.92	2.59	2.10	1.78	1.34	1.06	0.51	0.33	0.20	1.04	106.3	5.57	1.66
.056	7.67	6.52	6.11	5.67	5.32	4.95	4.60	3.99	3.39	2.97	2.63	2.15	1.81	1.36	1.08	0.52	0.34	0.20	1.05	108.5	5.64	1.65
058	7.78	6.61	6.19	5.74	5.39	5.02	4.66	4.05	3.43	3.02	2.68	2.19	1.85	1.39	1.10	0.53	0.35	0.21	1.06	110.6	5.72	1.64
.060	7.88	6.70	6.27	5.81	5.46	5.09	4.72	4.11	3.47	3.06	2.72	2.23	1.87	1.42	1.12	0.54	0.36	0.21	1.07	112.7	5.79	1.63
.062	7.99	6.79	6.35	5.89	5.53	5.16	4.78	4.17	3.52	3.11	2.77	2.23	1.88	1.44	1.15	0.56	0.36	0.22	1.08	114.8	5.86	1.62
.064	8.10	6.87	6.44	5.96	5.60	5.22	4.84	4.23	3.56	3.16	2.81	2.27	1.91	1.47	1.17	0.57	0.37	0.22	1.09	116.9	5.94	1.61
.066	8.20	6.96	6.52	6.04	5.67	5.29	4.90	4.29	3.60	3.20	2.86	2.31	1.94	1.49	1.19	0.58	0.38	0.23	1.10	119.1	6.01	1.60
.068	8.31	7.05	6.60	6.11	5.74	5.36	4.96	4.35	3.66	3.25	2.90	2.35	1.97	1.52	1.21	0.59	0.39	0.23	1.11	121.2	6.08	1.59
.070	8.41	7.13	6.68	6.19	5.82	5.43	5.02	4.40	3.72	3.29	2.94	2.38	2.01	1.55	1.24	0.61	0.40	0.24	1.12	123.3	6.16	1.58
.072	8.52	7.22	6.76	6.26	5.89	5.49	5.08	4.35	3.77	3.34	2.99	2.42	2.04	1.55	1.24	0.61	0.40	0.24	1.13	125.4	6.23	1.57
.074	8.62	7.31	6.84	6.34	5.96	5.56	5.14	4.41	3.83	3.38	3.03	2.46	2.08	1.57	1.27	0.62	0.41	0.24	1.14	127.5	6.30	1.56
.076	8.73	7.40	6.92	6.41	6.03	5.63	5.20	4.46	3.88	3.43	3.07	2.50	2.12	1.60	1.29	0.64	0.42	0.25	1.15	129.7	6.38	1.55
.078	8.84	7.48	7.00	5.49	6.10	5.69	5.26	4.52	3.94	3.47	3.12	2.53	2.12	1.62	1.31	0.64	0.43	0.25	1.16	131.8	6.45	1.54
.080	8.94	7.57	7.09	6.56	6.17	5.76	5.32	4.57	4.00	3.52	3.12	2.57	2.15	1.64	1.33	0.66	0.43	0.26	1.17	133.9	6.52	1.53

VALUES OF MOMENT MULTIPLIERS δ

L/De	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
	VALUES OF ULTIMATE STRESS P_u/A_g IN KSI																					
2.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02
3.0	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04	1.05	1.05
4.0	1.00	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.07	1.08	1.08	1.09
5.0	1.00	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.06	1.08	1.09	1.10	1.11	1.13	1.14	1.15
6.0	1.01	1.01	1.02	1.02	1.03	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.08	1.09	1.10	1.11	1.13	1.15	1.17	1.19	1.21	1.23
7.0	1.01	1.02	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.16	1.19	1.22	1.25	1.28	1.31	1.35
8.0	1.01	1.02	1.03	1.04	1.05	1.07	1.08	1.09	1.10	1.12	1.13	1.14	1.16	1.17	1.18	1.22	1.26	1.30	1.35	1.40	1.45	1.51
9.0	1.01	1.02	1.04	1.06	1.07	1.09	1.10	1.12	1.13	1.15	1.17	1.19	1.21	1.23	1.25	1.30	1.36	1.42	1.49	1.57	1.65	1.74
10.0	1.02	1.03	1.05	1.07	1.09	1.11	1.13	1.15	1.17	1.19	1.22	1.24	1.27	1.29	1.32	1.40	1.48	1.57	1.68	1.80	1.95	2.11
11.0	1.02	1.04	1.06	1.09	1.11	1.13	1.16	1.19	1.21	1.24	1.28	1.31	1.34	1.38	1.42	1.52	1.65	1.79	1.96	2.17	2.43	2.76
12.0	1.02	1.05	1.08	1.10	1.13	1.16	1.20	1.23	1.27	1.30	1.35	1.39	1.44	1.49	1.54	1.69	1.88	2.11	2.40	2.79	3.34	4.14
13.0	1.03	1.06	1.09	1.12	1.16	1.20	1.24	1.28	1.33	1.38	1.43	1.49	1.55	1.62	1.70	1.92	2.21	2.61	3.17	4.06	5.62	9.13
14.0	1.03	1.07	1.11	1.15	1.19	1.24	1.29	1.34	1.40	1.47	1.54	1.62	1.70	1.80	1.91	2.25	2.74	3.51	4.86	7.92		
15.0	1.04	1.08	1.12	1.17	1.22	1.28	1.34	1.41	1.49	1.57	1.67	1.78	1.90	2.04	2.21	2.76	3.70	5.58				
16.0	1.04	1.09	1.14	1.20	1.26	1.33	1.41	1.50	1.60	1.71	1.84	1.99	2.17	2.39	2.65	3.65	5.88					
17.0	1.05	1.10	1.16	1.23	1.31	1.39	1.49	1.60	1.73	1.88	2.06	2.28	2.56	2.91	3.36	5.55						
18.0	1.06	1.12	1.19	1.27	1.36	1.46	1.58	1.72	1.90	2.11	2.37	2.70	3.15	3.78	4.71							

VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI Y = .75

P_g Steel Ratio	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO δe/D																					
.010	5.28	4.57	4.30	4.02	3.76	3.51	3.26	2.72	2.30	1.92	1.63	1.16	0.87	0.56	0.41	0.17	0.10	0.06	1.00	65.7	4.36	2.19
.012	5.39	4.67	4.39	4.11	3.85	3.59	3.34	2.81	2.40	2.01	1.74	1.26	0.96	0.63	0.46	0.19	0.12	0.07	1.00	69.0	4.44	2.20
.014	5.50	4.77	4.48	4.20	3.93	3.68	3.42	2.90	2.48	2.11	1.83	1.37	1.05	0.70	0.51	0.22	0.14	0.08	1.00	72.3	4.52	2.20
.016	5.61	4.86	4.58	4.29	4.02	3.76	3.50	2.99	2.56	2.21	1.90	1.43	1.15	0.76	0.57	0.24	0.15	0.09	1.00	75.6	4.60	2.21
.018	5.72	4.96	4.67	4.38	4.10	3.85	3.58	3.07	2.63	2.30	1.97	1.52	1.20	0.83	0.62	0.27	0.17	0.10	1.00	78.9	4.68	2.22
.020	5.82	5.06	4.76	4.47	4.19	3.93	3.67	3.15	2.70	2.38	2.06	1.60	1.27	0.89	0.66	0.29	0.18	0.11	1.00	82.2	4.76	2.22
.022	5.93	5.15	4.85	4.56	4.27	4.01	3.75	3.23	2.76	2.40	2.14	1.67	1.34	0.94	0.71	0.31	0.20	0.12	1.00	85.5	4.84	2.23
.024	6.04	5.25	4.94	4.64	4.35	4.10	3.83	3.31	2.83	2.47	2.22	1.74	1.41	1.00	0.76	0.33	0.21	0.12	1.00	88.8	4.91	2.23
.026	6.15	5.35	5.03	4.73	4.43	4.18	3.91	3.38	2.88	2.54	2.24	1.80	1.48	1.04	0.80	0.35	0.23	0.13	1.00	92.2	4.99	2.24
.028	6.26	5.44	5.12	4.82	4.51	4.26	3.99	3.46	2.96	2.61	2.31	1.88	1.54	1.08	0.84	0.38	0.24	0.14	1.00	95.5	5.07	2.25
.030	6.37	5.54	5.21	4.91	4.60	4.34	4.07	3.53	3.04	2.67	2.37	1.92	1.58	1.13	0.88	0.40	0.25	0.15	1.00	98.8	5.15	2.25
.032	6.48	5.64	5.30	5.00	4.68	4.42	4.15	3.60	3.12	2.74	2.44	1.98	1.63	1.19	0.92	0.42	0.27	0.16	1.02	102.1	5.23	2.26
.034	6.58	5.73	5.39	5.08	4.76	4.50	4.23	3.68	3.19	2.84	2.50	2.05	1.69	1.22	0.95	0.43	0.28	0.16	1.04	105.4	5.31	2.26
036	6.69	5.83	5.48	5.17	4.84	4.58	4.31	3.75	3.27	2.90	2.56	2.08	1.74	1.27	0.99	0.45	0.29	0.17	1.05	108.7	5.38	2.27
.038	6.80	5.93	5.57	5.26	4.92	4.66	4.39	3.82	3.34	2.95	2.62	2.14	1.80	1.32	1.02	0.47	0.31	0.18	1.07	112.0	5.46	2.27
.040	6.91	6.02	5.66	5.35	5.01	4.74	4.47	3.88	3.41	3.00	2.68	2.19	1.84	1.35	1.06	0.49	0.32	0.19	1.08	115.4	5.54	2.28
.042	7.02	6.12	5.75	5.43	5.09	4.8[illegible]	4.55	3.95	3.49	3.05	2.74	2.24	1.89	1.40	1.10	0.51	0.33	0.19	1.10	118.7	5.62	2.29
.044	7.13	6.21	5.84	5.52	5.18	4.90	4.62	4.02	3.56	3.10	2.80	2.29	1.93	1.44	1.13	0.53	0.34	0.20	1.11	122.0	5.70	2.29
.046	7.25	6.31	5.93	5.61	5.26	4.97	4.70	4.09	3.63	3.15	2.85	2.34	2.00	1.48	1.16	0.55	0.35	0.21	1.13	125.3	5.78	2.30
.048	7.36	6.41	6.02	5.69	5.34	5.05	4.78	4.15	3.61	3.20	2.91	2.40	2.02	1.51	1.20	0.56	0.37	0.22	1.14	128.6	5.86	2.30
.050	7.47	6.50	6.11	5.78	5.43	5.13	4.86	4.22	3.68	3.27	2.96	2.45	2.06	1.56	1.23	0.58	0.38	0.22	1.16	131.9	5.93	2.31
.052	7.58	6.60	6.20	5.87	5.51	5.21	4.93	4.28	3.74	3.34	3.01	2.50	2.11	1.59	1.26	0.60	0.39	0.23	1.17	135.2	6.01	2.32
.054	7.69	6.70	6.29	5.95	5.59	5.29	5.01	4.35	3.80	3.41	3.07	2.55	2.15	1.63	1.29	0.62	0.40	0.24	1.19	138.5	6.09	2.32
.056	7.81	6.79	6.38	6.04	5.68	5.36	5.09	4.41	3.87	3.48	3.12	2.61	2.20	1.67	1.32	0.63	0.41	0.24	1.20	141.9	6.17	2.33
.058	7.92	6.89	6.47	6.13	5.76	5.44	5.16	4.47	3.93	3.55	3.17	2.62	2.24	1.71	1.35	0.65	0.42	0.25	1.22	145.2	6.25	2.33
.060	8.03	6.98	6.56	6.21	5.84	5.52	5.24	4.54	3.99	3.61	3.22	2.67	2.28	1.74	1.39	0.67	0.44	0.26	1.23	148.5	6.33	2.34
062	8.14	7.08	6.65	6.30	5.93	5.59	5.31	4.60	4.06	3.60	3.30	2.72	2.33	1.78	1.41	0.68	0.45	0.26	1.24	151.8	6.41	2.35
.064	8.25	7.18	6.75	6.39	6.01	5.67	5.39	4.66	4.12	3.66	3.35	2.77	2.37	1.82	1.45	0.70	0.46	0.27	1.26	155.1	6.48	2.35
.066	8.36	7.27	6.84	6.47	6.09	5.75	5.46	4.73	4.18	3.72	3.39	2.81	2.42	1.85	1.48	0.72	0.47	0.28	1.27	158.4	6.56	2.36
.068	8.48	7.37	6.93	6.56	6.18	5.82	5.54	4.79	4.25	3.78	3.43	2.86	2.44	1.88	1.51	0.73	0.48	0.28	1.28	161.7	6.64	2.36
.070	8.59	7.46	7.02	6.64	6.26	5.90	5.61	4.85	4.31	3.83	3.47	2.91	2.48	1.90	1.54	0.75	0.49	0.29	1.30	165.1	6.72	2.37
.072	8.70	7.56	7.11	6.73	6.34	5.98	5.69	4.91	4.37	3.89	3.51	2.95	2.52	1.94	1.57	0.77	0.50	0.30	1.31	168.4	6.80	2.37
.074	8.81	7.66	7.20	6.82	6.43	6.05	5.76	4.98	4.43	3.95	3.56	3.00	2.56	1.97	1.59	0.78	0.51	0.30	1.32	171.7	6.88	2.38
.076	8.92	7.75	7.30	6.90	6.51	6.13	5.84	5.05	4.49	4.01	3.62	3.05	2.60	2.01	1.62	0.80	0.52	0.31	1.34	175.0	6.95	2.39
.078	9.03	7.85	7.39	6.99	6.59	6.20	5.91	5.12	4.55	4.06	3.68	3.09	2.65	2.04	1.65	0.81	0.53	0.32	1.35	178.3	7.03	2.39
.080	9.15	7.94	7.48	7.07	6.67	6.28	5.99	5.19	4.62	4.12	3.75	3.14	2.69	2.08	1.68	0.83	0.54	0.32	1.36	181.6	7.11	2.40

VALUES OF ULTIMATE AXIAL STRESS P_u/A_g IN KSI Y = .9

P_g Steel Ratio	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40	0.50	0.60	0.80	1.00	2.00	3.00	5.00	Eff.D Ratio D_e/D	EI/D^4	P_u/A_g at $\epsilon_s=0$	P_u/A_g at $\epsilon_s=\epsilon_y$
	VALUES OF ECCENTRICITY RATIO δe/D																					
.010	5.30	4.63	4.36	4.10	3.84	3.61	3.37	2.87	2.42	2.05	1.75	1.28	0.95	0.62	0.44	0.18	0.11	0.06	1.00	72.9	4.74	2.48
.012	5.42	4.73	4.46	4.20	3.94	3.71	3.47	2.98	2.53	2.17	1.87	1.38	1.07	0.70	0.51	0.21	0.13	0.08	1.00	77.7	4.82	2.50
.014	5.53	4.84	4.56	4.30	4.03	3.81	3.57	3.08	2.62	2.28	1.96	1.51	1.17	0.78	0.58	0.24	0.15	0.09	1.00	82.5	4.91	2.51
.016	5.64	4.94	4.66	4.40	4.13	3.90	3.67	3.17	2.72	2.38	2.07	1.58	1.25	0.85	0.63	0.27	0.17	0.10	1.00	87.3	4.99	2.53
.018	5.75	5.05	4.76	4.50	4.23	4.00	3.77	3.26	2.82	2.47	2.17	1.68	1.33	0.93	0.69	0.30	0.19	0.11	1.00	92.0	5.07	2.54
.020	5.87	5.15	4.86	4.60	4.33	4.09	3.86	3.35	2.92	2.56	2.27	1.77	1.42	0.99	0.74	0.32	0.20	0.12	1.00	96.8	5.15	2.55
.022	5.98	5.26	4.96	4.70	4.43	4.18	3.96	3.43	3.02	2.64	2.35	1.87	1.50	1.06	0.80	0.35	0.22	0.13	1.02	101.6	5.23	2.57
.024	6.09	5.36	5.06	4.80	4.52	4.27	4.05	3.51	3.11	2.72	2.44	1.93	1.58	1.12	0.85	0.37	0.24	0.14	1.04	106.3	5.31	2.58
.026	6.21	5.46	5.16	4.89	4.62	4.36	4.14	3.59	3.20	2.79	2.51	2.01	1.65	1.18	0.90	0.40	0.26	0.15	1.06	111.1	5.40	2.60
.028	6.32	5.57	5.26	4.99	4.72	4.44	4.23	3.67	3.28	2.87	2.59	2.10	1.72	1.23	0.95	0.43	0.27	0.16	1.09	115.9	5.48	2.61
.030	6.44	5.67	5.37	5.08	4.81	4.53	4.31	3.74	3.36	2.96	2.66	2.18	1.79	1.29	1.00	0.45	0.29	0.17	1.11	120.7	5.56	2.63
.032	6.56	5.77	5.47	5.18	4.91	4.62	4.40	3.83	3.44	3.05	2.73	2.26	1.87	1.36	1.05	0.47	0.30	0.18	1.13	125.4	5.64	2.64
.034	6.68	5.87	5.57	5.27	5.00	4.71	4.49	3.92	3.52	3.14	2.79	2.33	1.91	1.40	1.08	0.50	0.32	0.19	1.15	130.2	5.72	2.66
.036	6.79	5.98	5.67	5.37	5.09	4.81	4.57	4.01	3.60	3.22	2.85	2.36	1.98	1.45	1.13	0.52	0.34	0.20	1.17	135.0	5.81	2.67
.038	6.91	6.08	5.77	5.46	5.19	4.90	4.66	4.09	3.67	3.23	2.91	2.42	2.05	1.51	1.17	0.54	0.35	0.20	1.19	139.7	5.89	2.69
.040	7.02	6.18	5.87	5.55	5.28	4.99	4.74	4.18	3.74	3.30	2.99	2.49	2.09	1.56	1.22	0.57	0.37	0.21	1.21	144.5	5.97	2.70
.042	7.14	6.28	5.97	5.65	5.37	5.08	4.82	4.26	3.81	3.37	3.07	2.55	2.15	1.61	1.26	0.59	0.38	0.22	1.23	149.3	6.05	2.72
.044	7.26	6.38	6.07	5.74	5.46	5.17	4.90	4.35	3.88	3.45	3.15	2.61	2.21	1.66	1.31	0.61	0.40	0.23	1.25	154.1	6.13	2.73
.046	7.37	6.48	6.17	5.83	5.55	5.26	4.99	4.43	3.95	3.52	3.23	2.67	2.26	1.71	1.34	0.63	0.41	0.24	1.27	158.8	6.21	2.74
.048	7.49	6.59	6.27	5.92	5.65	5.35	5.07	4.51	4.02	3.59	3.24	2.72	2.32	1.75	1.38	0.65	0.42	0.25	1.29	163.6	6.30	2.76
.050	7.60	6.69	6.36	6.02	5.74	5.44	5.15	4.60	4.09	3.66	3.30	2.78	2.38	1.80	1.42	0.67	0.44	0.26	1.31	168.4	6.38	2.77
052	7.71	6.79	6.46	6.11	5.83	5.53	5.23	4.68	4.15	3.73	3.37	2.84	2.43	1.84	1.47	0.69	0.45	0.27	1.33	173.1	6.46	2.79
054	7.83	6.89	6.56	6.21	5.92	5.62	5.31	4.76	4.22	3.79	3.44	2.93	2.49	1.88	1.51	0.72	0.47	0.27	1.35	177.9	6.54	2.80
.056	7.94	6.99	6.66	6.31	6.01	5.71	5.40	4.84	4.28	3.86	3.50	2.98	2.54	1.94	1.54	0.74	0.48	0.28	1.36	182.7	6.62	2.82
.058	8.05	7.09	6.76	6.40	6.10	5.80	5.49	4.92	4.35	3.93	3.56	3.03	2.59	1.97	1.58	0.76	0.50	0.29	1.38	187.5	6.71	2.83
.060	8.17	7.20	6.86	6.50	6.19	5.89	5.58	5.00	4.41	4.00	3.63	3.08	2.64	2.01	1.62	0.78	0.51	0.30	1.40	192.2	6.79	2.85
.062	8.28	7.30	6.95	6.59	6.28	5.98	5.66	5.07	4.47	4.06	3.69	3.12	2.70	2.06	1.66	0.80	0.52	0.31	1.42	197.0	6.87	2.86
.064	8.38	7.40	7.05	6.69	6.37	6.07	5.75	5.15	4.55	4.13	3.76	3.17	2.75	2.10	1.69	0.82	0.54	0.32	1.43	201.8	6.95	2.88
.066	8.49	7.51	7.15	6.78	6.46	6.15	5.84	5.23	4.63	4.20	3.82	3.21	2.79	2.15	1.73	0.84	0.55	0.32	1.45	206.5	7.03	2.89
.068	8.61	7.61	7.25	6.88	6.54	6.24	5.92	5.31	4.71	4.26	3.88	3.28	2.84	2.19	1.77	0.86	0.56	0.33	1.47	211.3	7.12	2.90
070	8.72	7.71	7.35	6.98	6.63	6.33	6.01	5.39	4.79	4.33	3.95	3.35	2.89	2.24	1.80	0.88	0.58	0.34	1.48	216.1	7.20	2.92
.072	8.83	7.82	7.44	7.07	6.72	6.42	6.09	5.46	4.86	4.39	4.01	3.42	2.94	2.28	1.83	0.90	0.59	0.35	1.50	220.9	7.28	2.93
.074	8.96	7.92	7.54	7.17	6.81	6.50	6.18	5.54	4.94	4.46	4.07	3.43	2.99	2.33	1.88	0.92	0.60	0.36	1.52	225.6	7.36	2.95
.076	9.08	8.03	7.64	7.26	6.90	6.59	6.27	5.61	5.01	4.52	4.13	3.48	3.04	2.37	1.90	0.94	0.62	0.36	1.53	230.4	7.44	2.96
.078	9.20	8.13	7.73	7.36	6.99	6.68	6.35	5.69	5.09	4.65	4.19	3.53	3.08	2.42	1.93	0.96	0.63	0.37	1.55	235.2	7.52	2.98
.080	9.33	8.23	7.83	7.45	7.07	6.76	6.44	5.77	5.16	4.71	4.26	3.59	3.13	2.44	1.97	0.98	0.64	0.38	1.56	239.9	7.61	2.99

4a. Calculate $D = \{4\ P_u/[\pi(P_u/A_g)_{Table}]\}^{0.5}$ If this is first time through Step 4a, skip to Step 5.	9.90	14.14	10.30
4b. Calculate $D = 0.5(D_{latest} + D_{previous})$; then find		12.02	11.16
$(P_u/A_g)_{Calculated} = 4\ P_u/(\pi D^2)$		2.74	3.18
5. Using same table as in Step 3 and p_g, find D_e/D;	1.27	NC	NC
calculate D_e; then using small table at top of right	12.57	15.27	14.17
page (moment multiplier table), calculate L/D_e for left	11.46	9.43	10.16
scale, use $(P_u/A_g)_{(latest)}$ and interpolate to read δ.	3.81	1.50	1.81
If new δ is close to δ in Step 3 (say within about 1% or 2%), skip to Step 7.**			
6. Correct e for code minimum (Step 2) and experience. Use latest values of all parameters as initial values and repeat Steps 3-5.	NC	NC	NC
7. Calculate required spiral steel ratio p_s using E Equation 6-35 (in Step 8 of final design procedure just above).[81]			0.029††

The rebar scheme and related assumptions are discussed in the next section.[81]

** Or if D_{latest} and $D_{previous}$ (Step 4) were within about 1% or 2%, user could skip from end of Step 5 to Step 7.

†† Using D = 11.20, the final value of several trials.

H. Arch and Conduit Structures - Corrugated-Steel and Reinforced Concrete

As an alternative to the usual and expensive box-like and rectilinear structures contemplated in the above design procedures[81] and for most buildings, corrugated-steel arch structures and conduits, as well as reinforced concrete circular conduits (sewer pipe), offer many advantages and are worth careful consideration. Design, particularly of the conduits, is largely empirical, but fortunately there have been applicable full-scale nuclear weapons field tests conducted (1957), the reports of which are now unclassified. Only such tested structures, or their closest currently available product, are considered further herein.

Buried Corrugated-Steel Arch Structures. Nuclear weapons field tests have included buried corrugated-steel arch structures [specifically the 25'x48' (170°) prefabricated ammunition-storage magazine only slightly modified from that used at the time by the U. S. Navy] in such operations held between 1953 and 1958, both at the Nevada Test Site (NTS) and the Pacific Proving Grounds of the former Atomic Energy Commission. The test project of most interest to this brief review was Project 3.3 of Operation PLUMBBOB, exposed to nuclear effects in Shot Priscilla, 37 kt from a balloon at 700 ft above ground level on June 24, 1957 at 1330.[1,90] The test report is detailed and available to the public.[90] While three structures were tested, the one tested without added 6I12.5 arch ribs at 4 ft centers is of principal interest herein; this Structure 3.3b was a stock ammo magazine modified only as to end bulkheads.

A related Project 3.2 on tests of buried R/C and corrugated-steel conduits was covered with Project 3.3 in a brief article published[91] in April 1958, then used shortly thereafter in testimony before a Congressional Subcommittee.[92] An extract from the testimony follows:

CIVIL DEFENSE

Part I—Atomic Shelter Tests

Part II—Reorganization Plan No. 1 of 1958

(Providing new arrangements for the conduct of Federal defense mobilization and civil defense functions)

HEARINGS

BEFORE A

SUBCOMMITTEE OF THE COMMITTEE ON GOVERNMENT OPERATIONS HOUSE OF REPRESENTATIVES

EIGHTY-FIFTH CONGRESS

SECOND SESSION

PART I—APRIL 30, MAY 1, 2, 5, AND 8, 1958

PART II—MAY 6 AND 7, 1958

Printed for the use of the Committee on Government Operations

STATEMENT OF COMDR. G. B. HOWE, UNITED STATES NAVY, HEAD, PASSIVE DEFENSE BRANCH, OFFICE OF CHIEF OF NAVAL OPERATIONS

Commander HOWE. Mr. Chairman and members of the committee: The Navy's protective construction policy includes the protective measures of dispersal, duplication, strengthening and underground construction. It is designed to protect personnel, equipment, and facilities against the effects of nuclear weapons. This policy, developed by the Joint Chiefs of Staff and coordinated by the Office of the Assistant Secretary of Defense, Properties and Installations, is aimed at increasing the survival probability of weapons systems essential for the conduct of combat missions.

The Navy does not have a shelter program, per se. Shelters are provided only to those personnel essential to the operation of highly classified essential facilities in the same manner as protection is afforded to the equipment and facilities these personnel operate.

The Bureau of Yards and Docks has overall technical cognizance of protective construction, including shelter design and actual construction. Design projects and studies are performed by the Bureau of Yards and Docks and its Naval Civil Engineering Research and Evaluation Laboratory, and also for BuDocks by the Naval Research Laboratory, the Naval Radiological Defense Laboratory, and private engineering firms.

The Navy feels that the state of the art of shelter design is well developed. Continuing emphasis is being put on lowering the cost of shelters and other protective construction.

A variety of studies on shelters and other protective construction measures have been sponsored and conducted by the Navy. One of these studies completed in 1956 was for the purpose of determining the total protective construction requirements of the naval shore establishment. This completed study is in fact the Navy's long-range plan for protective construction.

The Navy intends to pursue this plan.

Individual protective construction items will be considered in the annual military construction program in accordance with the priorities assigned.

These projects will, of course, compete with other military construction projects for the funds available.

I purposely kept my statement short because my supporting witness, Commander H. L. Murphy, has the details which I think you would like to hear concerning the shelters tested.

Mr. HOLIFIELD. All right, we will proceed to his statement. Commander Murphy.

STATEMENT OF COMDR. H. L. MURPHY, CIVIL ENGINEER CORPS, UNITED STATES NAVAL RESERVE, DIRECTOR, PASSIVE DEFENSE DIVISION, BUREAU OF YARDS AND DOCKS

Commander MURPHY. Chairman Holifield and members of the subcommittee: It is my purpose to supplement the Navy general statement with additional data, requested by this subcommittee, dealing with engineering and related technical matters.

6-120

Specifically, such data include discussion of two Navy Bureau of Yards and Docks-sponsored structures (shelter) projects in the 1957 Plumbbob tests in Nevada, and a summary of selected studies performed by or for the Bureau of Yards and Docks bearing upon the problems of shelter against nuclear weapons effects.

Because it was written for informative purposes similar to the aims of this statement, an article being published in the forthcoming issue of the BuDocks Technical Digest is incorporated herein and will be amplified by additional data and figures.

In a continuing search over many years, the Bureau has considered many structures offering promise of low-cost shelter against atomic, biological, or chemical warfare attack. This search has turned up excellent shelters constructed or precast thin-shell concrete sections (bolted into dome or gable structure), or of corrugated steel plates (circular arch structure.)[1] The latter, commonly known as an ammunition magazine and manufactured as a stock item by several firms, has been detailed with or without earth cover, including several cover configurations. The significant change over earlier versions is that the earth cover is now extended horizontally to a plane through the structure base at approximately 45 degrees, then sloped to natural grade (Figure 2 is for balanced cut-and-fill), thus reducing the sensitivity of the arch structure to the (asymmetric) blast drag (wind) loading.[2] Figures 1 and 2 show the latest concepts of this buried shelter tested both with and without the steel ribs indicated.

More recently, consideration has also been given to use of standard sewer conduits and cattle-pass sections for shelter, the concept involving 2 to 4 parallel "runs" (50 to 200 feet long) connected by a crosshead structure with entranceway(s), decontamination spaces and equipment. Figure 3 depicts the test configuration used for evaluating the conduits only.

With careful construction techniques, in dry cohesive soils, 1957 tests[3] using kiloton-range weapons showed no significant deformation of the corrugated metal shelters and conduits, shown herewith, under the following approximate blast peak overpressures: Corrugated metal arch shelter, without ribs—50 to 60 psi; with ribs—90 to 100 psi; reinforced concrete sewer and circular corrugated metal pipes—130 to 140 psi; corrugated metal cattle-pass—150 to 160 psi.

It is highly probably that all of these structures would satisfactorily withstand much higher peak overpressures, for example, conduits to 200 psi or more, whether from kiloton or megaton range weapons. Various soil types could, of course, modify these structural resistance values. Protection against all comparable initial and residual (fallout) radiation effects is incorporated by varying the thickness of earth cover and sandbagging details.

Detailed discussion of protective shelters[1] is inappropriate here; however, a few comments to augment the figures may be of interest. Conduits tested were 8 ft. precast concrete sewer (ASTM C75-55) and 8 ft. corrugated steel plate (10 gage) pipes, and corrugated steel plate (10 gage) cattle-pass 7'8" x 5'10".

In figure 2, the plan is varied to suit use—mass shelter, operating center, sickbay—and whether to be a pressurized, nonmask shelter or one requiring individual protective masks. Entrance details are also varied: others might include a steep, narrow-tread, shipboard-type "ladder" in a slightly larger conduit and hatch, or one similar to that of the standard FCDA (100 pounds per square inch) industrial shelter, figure 4. A trapdoor-and-sand emergency exit should be provided at the other end. Vents should include blast closures—possibly sliding steel door in the concrete "box" or high-pressure valve in the 8-inch, extra-heavy steel pipe—closed manually, or automatically by light, thermal or blast from the explosion. Floor should not be tied to the foundation, to allow the structure to "punch" downward slightly with the blast. Concrete shield walls could be used in lieu of sandbags, but the latter are easier to remove and replace, if necessary for equipment movement.

The "ribs" referred to in the article in connection with the modified ammunition magazine are 6-inch I-beams weighing 12½ pounds per linear foot (6I12.5). It should be made clear that the ammo magazine shelter shown is complete when erected without such "ribs," due to the corrugations running circumferentially.

[1] NavDocks TP-PL-8, Personnel Protective Shelters, June 1953 (under revision).
[2] The Effects of Nuclear Weapons (GPO), sec. 6.13.
[3] Classified reports by Lt. (jg.) G. H. Albright, CEC, USNR.

In contrast the so-called quonset-type structure is essentially a ribbed structure with a lighter gage corrugated metal covering. In fact, the ammo magazine corrugated steel plates in the arch are *not* in contact with the "ribs" as erected; contact is made only after the structure receives a very heavy load causing general deflection in the arch.

The ammo magazine shelter version without ribs was used by the Naval Radiological Defense Laboratory in their Plumbbob (1957) radiological shelter test which was discussed by Dr. Paul Tompkins in earlier testimony before this subcommittee. The earth cover and the entrance detail were, of course, differently designed due to the comparatively low blast pressures expected and received. This design version without ribs has been in BuDocks publications for several years, as is indicated by the article. The significant advance through 1957 tests has been in what we have learned about earth cover configurations.

Sheets 1, 2, and 3 provide supplementary sketches and data to those provided by the article. Sheet 1 includes technical details on the corrugated steel plates. Sheet 2 provides further information on the conduits. Sheet 3 shows one concept for using the pipe conduits in a large personnel shelter.

The plan shown in figure 2 includes biological and chemical warfare protection. Capacity might be 30 to 80 persons, depending on use, whether for one or both sexes, and the quantity of supplies to be stored inside the shelter. The "30" figure might be valid for such working spaces as control or communications centers. The "80" figure is considered approximately correct as an upper figure for personnel shelter and is based on approximately 10 square feet per person, a figure already cited several times to the subcommittee.

An engineering estimate of cost, prepared by BuDocks personnel in 1957, for construction of the ammo magazine shelter shown in figures 1 and 2, totaled $26,000 excluding land and any operating equipment and supplies, as well as emergency power and potable water tanks. This estimate was for construction in the Norfolk, Va., area, but the estimate can be related to various areas in the world through use of our published cost index.

Table I shows the aforementioned blast peak overpressures related to distances from ground zero for contact surface burst of several weapon yields; the latest known unclassified graph of pressure-distance data—reprint of talk on October 16, 1957, at A. S. C. E. annual meeting, New York City, by Capt. Ferd E. Anderson, Jr., Corps of Engineers, U. S. Army, Blast Division, AFSWP—has been used.

TABLE I

Peak overpressure (pounds per square inch)	Distance (feet)			
	20 kilotons	40 kilotons	1 megaton	20 megatons
200	670	845	2,460	6,680
160	725	915	2,670	7,250
140	775	975	2,850	7,750
100	895	1,130	3,300	8,950
60	1,115	1,405	4,110	11,150

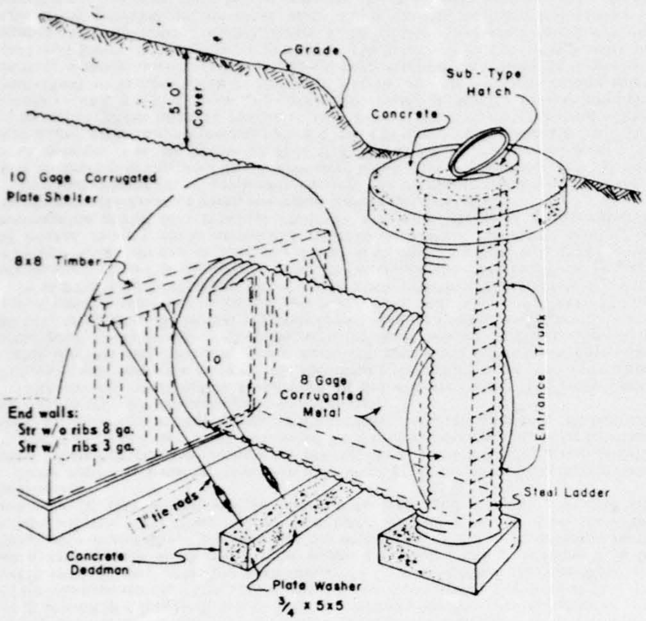


FIGURE 1.

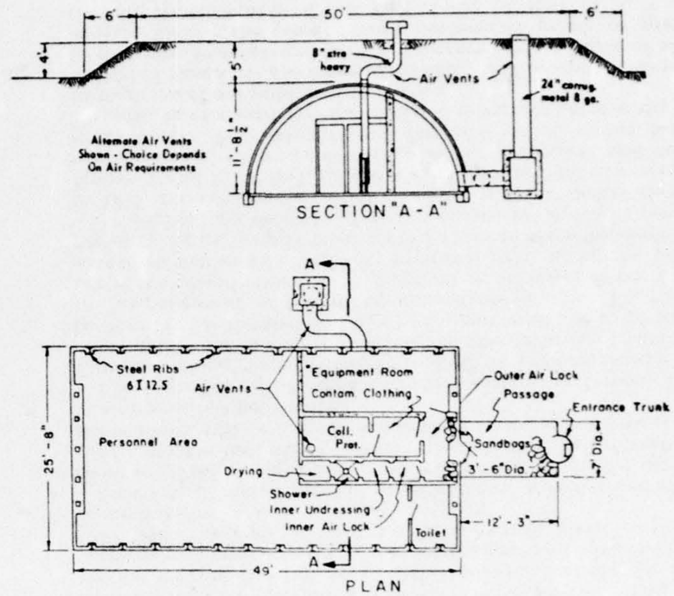


FIGURE 2.

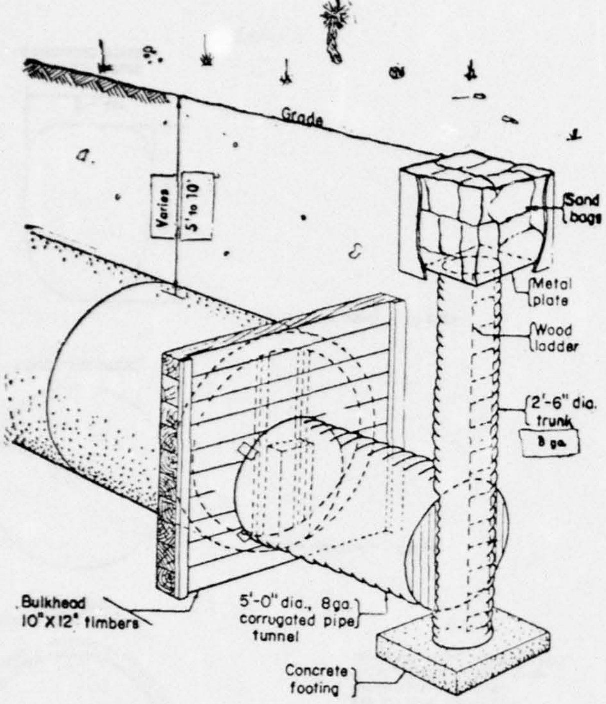


FIGURE 3

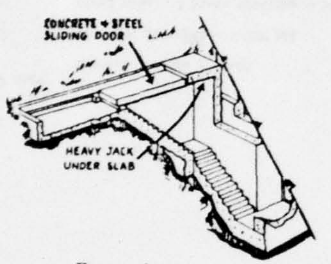
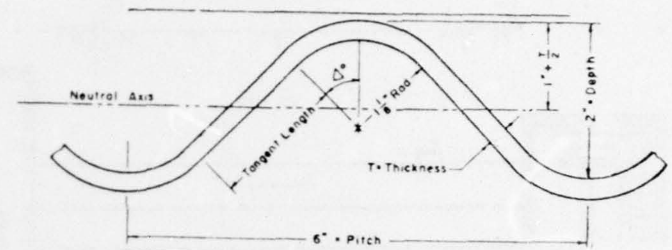


FIGURE 4.

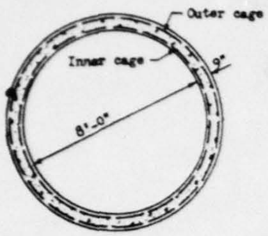


Properties	3 Gage	8 Gage	10 Gage
Thickness T (inch)	0.2451	0.1644	0.1345
Tangent Length (inch)	1.7377	1.8283	1.8606
Angle Δ°	45° 47'	45° 00'	44° 44'
Moment of Inertia (in^4) *	1.756	1.153	0.937
Area of Section (in^2)*	3.658	2.449	2.003
Section Modulus (in^3) *	1.564	1.066	0.878
Radius of Gyration (inch)	0.693	0.686	0.684

* Per foot of horizontal Projection

PROPERTIES OF CORRUGATED STEEL PLATES

SHEET 1.

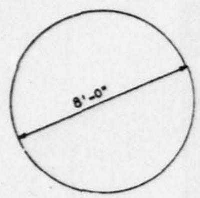


PRE - CAST CONCRETE
SEWER PIPE

Section lengths - 5'-0"

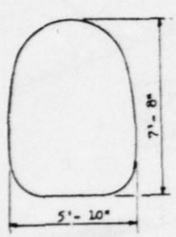
Concrete Strength - 3,000 psi

Steel Area - 2 lines totaling 0.57 sq. in./lin,ft. (inner cage 3/8"@4"c-c; outer cage 5/16"@3-3/4" c-c; cage reinf. circumferential and 1" from respective surface; longitudinal reinf. sufficient to keep cages in shape. ASTM C75-55).



CORRUGATED STEEL

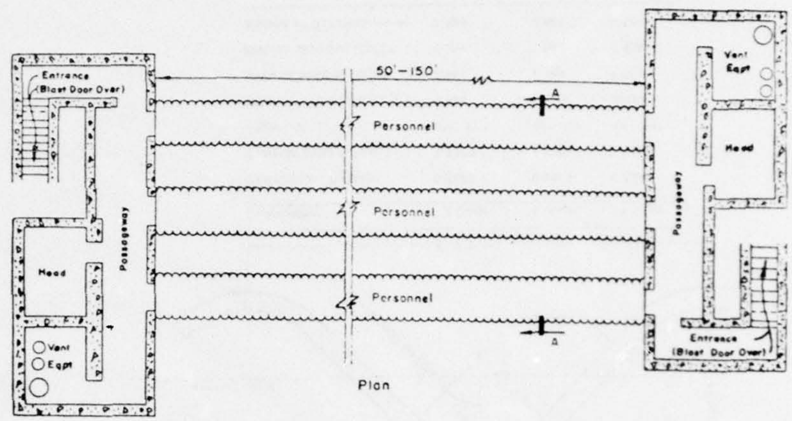
Corrugated Steel - 10 gage



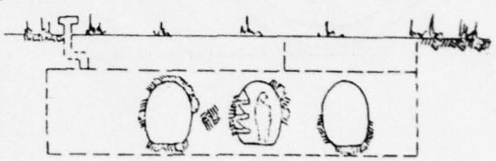
CATTLE - PASS
CORRUGATED STEEL

Corrugated Steel - 10 gage

SHEET 2.



Plan



Section AA

SHEET 3.

With the declassification of the test report,[90] further data and details became available - selected items are provided in the following paragraphs - and the report should be obtained and used by any professionals seriously contemplating use of the arch structure tested.

Peak overpressure at the earth's surface was 60 psi with a positive phase duration of 361 msec; peak internal pressure was 1.0 psi; peak vertical floor acceleration was less than 3 g's; average displacement of footings at midlength of the structure was 1-1/2 in.; maximum and residual deflections of arch crown relative to the floor were 4 in. and 2-3/4 in., respectively; and earth cover was 5 ft; all referring to Structure 3.3b.

Backfilling operations - of the greatest importance because a significant part of the structure's strength was due to passive resistance of the soil, developed by deformation of the flexible arch into the soil backfill - followed good conventional construction practices. It is important to add, however, that backfilling was very closely inspected, close maintenance of the arch shape was obtained, and all such work was supported by complete soil analyses and testing throughout the construction work. Soil for backfill was imported from a nearby gravel pit and consisted of a gravelly, silty sand, rather than use being made of the in situ silt from the dry lakebed of Frenchman Flat.

The floor, a 4-in. concrete slab, was separated from the foundation walls by a 1/2-in. impregnated, expansion-joint filler to achieve three purposes: (1) reduce acceleration forces transmitted to all other structure portions from being transmitted to personnel and/or equipment located on the floor slab; (2) permit use of an economical (thin) floor slab relative to one that would be required to withstand the full forces transmitted to the arch structure; and (3) permit a significant displacement (downward) of the arch structure and its foundation walls, thus absorbing energy from the detonation's blast, yet cause only minor cracking or other effect on the floor slab.

A tendency was noted for slippage along horizontal seams in the arch corrugated-steel plates, thus reducing the arch circumferential length;

in no case, however, was a sheared bolt observed. Minor racking of interior partitions, doors, and airlocks was noted; however, all doors opened without forcing upcn initial postshot entry. All endwalls were in excellent condition postshot. No significant damage occurred to plumbing and electrical fixtures installed at the 60-psi range.

Figure 6-13 supplements Figure 2 of the above Congressional testimony extract by showing the extent of earth cover in both directions. Cover was balanced cut-and-fill, and the location of shallow banks (1.5:1) at a substantial distance laterally from the arch structure is extremely important, as demonstrated by earlier tests of the ammo magazine wherein arch failure occurred under other cover configurations.[90]

Selected portions of the construction specifications that were used are included in the report, as are details on the soil-survey program and the backfill operations.[90(App.A)]

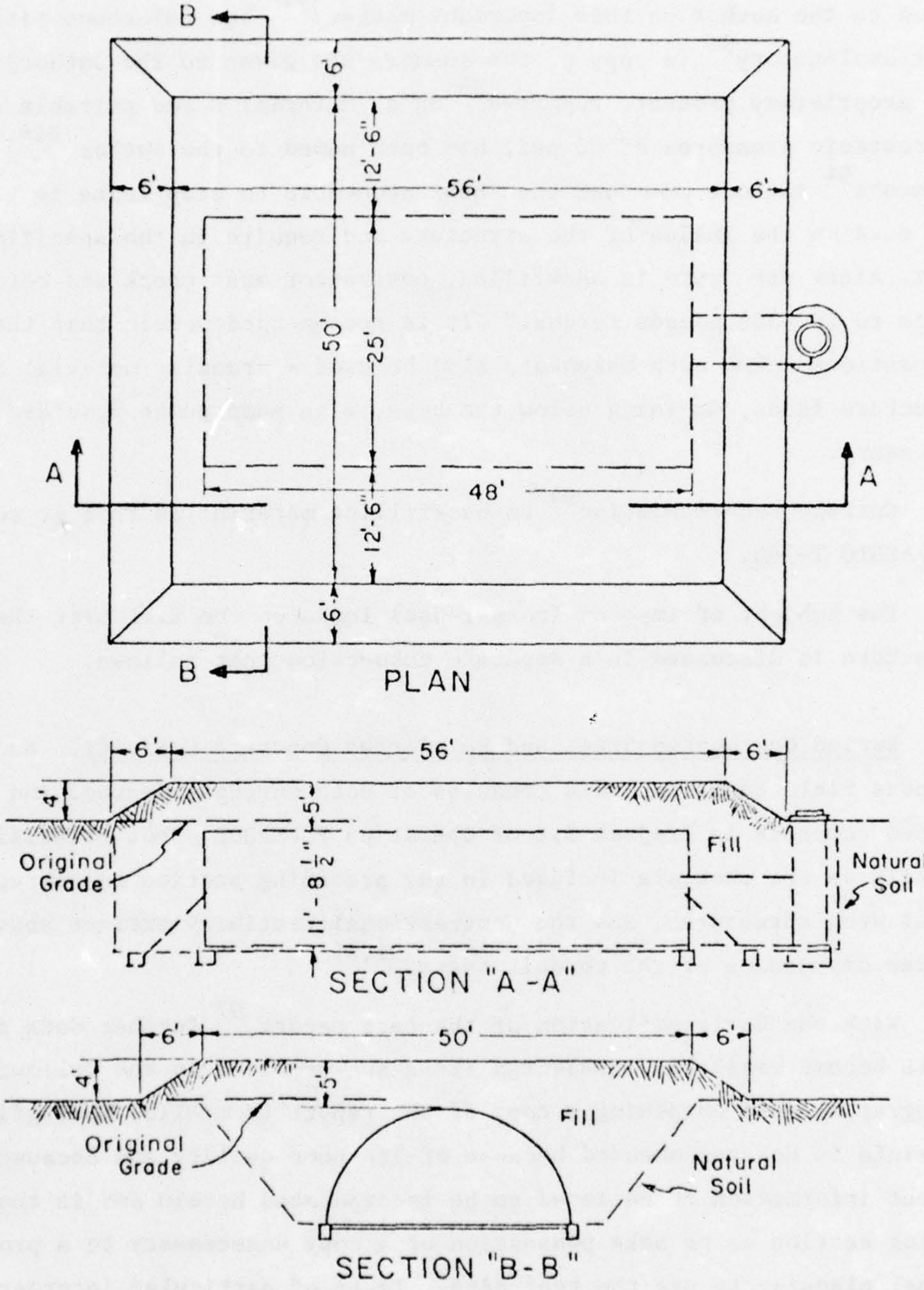
Moving from the time of the nuclear field tests (1957) to the present time of writing (5/76):

Current manufacturer's catalog for the closest similar product to the tested Structure 3.3b shows the same corrugations in use and arch structures of many span-rise configurations; e.g., using the test structure span-rise ratio (25'8":11'8½" or 2.19), available structures include one with span-rise values of 25'0":11'3½" or 11'8½" and another 26'0":11'10".[93] An estimate of installed cost for the latter structure, excluding all earthwork and the base slab, is as follows (for Austin, Texas):[94]

	10 ga.	1 ga.
Structure including base channels, matls/lf	\$ 200	\$ 300
Erection/lf	32	45
End bulkheads, 8 ga., matls & labor, each (excluding tie-back structures)	4000	4000

The purpose of including the estimate for a 1 ga. structure is explained below.

A useful, pocket-size, installation manual is available and includes suggested lateral spacing minimums for parallel corrugated-steel structures.[95]



Earth configuration for Structure 3.3, Operation Plumbbob.[90]

FIGURE 6-13

Sealing of seams in corrugated-steel structures located belowground is a difficult problem at best; comments and a reference have been provided to the author on this important matter:[94] The reference title is self-explanatory[96] (a copy of the summary was given to the author) and one proprietary product, reported[96] on as Material B and suitable for hydrostatic pressures of 60 psi, has been named to the author.[94*] Comments[94] include one that the "Best procedure to stop leaks is to have all nuts on the inside of the structure and require in the specifications that, after structure is backfilled, contractor must check and retighten bolts to 100-300 pounds torque." It is recommended herein that the usual precautions taken with basements also be used - granular material along structure faces, draining below the base, with sump pumps provided where necessary.

Current recommendation[94] on backfilling material is that it conform to AASHTO T-180.

The subject of imposed (normal-use) loads on the fill over the arch structure is discussed in a separate subsection that follows.

Buried Corrugated-Steel and Reinforced Concrete Conduits. Nuclear weapons field tests included conduits of both corrugated-steel and reinforced concrete in Project 3.2 of Operation PLUMBBOB, Shot Priscilla; details on the shot are included in the preceding section on corrugated-steel arch structures, and the Congressional testimony extract above includes discussion of the conduit tests.[91,92]

With the declassification of the test report,[97] further data and details became available - selected items are provided in the following paragraphs - but obtaining a copy of the report from NTIS, Springfield, Virginia is not recommended because of its poor quality and because sufficent information is believed to be incorporated herein and in the preceding section as to make possession of a copy unnecessary to a professional planning to use the test data. Tests of particular interest to the purposes of this section are:

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* Armco #101 Sealant Tape (for address, see Ref. 93).

Project/Conduit	Free-field Overpressure	Positive Phase Dur.	Earth Cover
3.2d Circular, corrug.stl., 8 ft diam.	126 psi	206 msec	7.5'
3.2e Circular, precast R/C, 8 ft i.d.	"	"	"
3.2f Cattle-Pass, corrug.stl.,5'10"x7'8" rise	"	"	5'

Further details on the above test conduits are shown in Figure 3 and Sheets 1-3 of the above Congressional Testimony extract.

All conduits tested showed no significant damage. Peak downward acceleration at the bottom of the tabulated conduits was about 5 g's or less; peak internal pressure was about 3 psi; and maximum vertical deflections, measured between invert and inside top of each conduit, were less than an inch. A tendency was noted for the circumferential dimension of corrugated-steel conduits to be reduced because of slippage along the horizontal seams; however, in no case was a sheared bolt observed.

Comments in the preceding section also apply to the conduits, such as those on backfill material, backfilling operations, and related soils controls. Cover was to normal grade, not balanced cut-and-fill as with the arch structures.

Construction specifications apparently parallel those applied to the arch structures; however, the quality of the conduits test report[97] (from NTIS) is too poor for reproduction, even very difficult to read.

Moving again from the time of the nuclear field tests (1957) to the present time of writing (5/76):

Current manufacturer's catalog for the closest similar product to the tested Structure 3.2f shows the same corrugations, dimensions and gages, the only change being a renaming to Junior Underpass, rather than the Cattle-Pass of the tests.[93] Multi-Plate and helical corrugated-steel pipes are also available in a variety of sizes, including the 8-ft diameter tested. An estimate of installed cost for the Junior Underpass of the same corrugations, dimensions and gage tested in 1957, excluding all earthwork, is as follows (for Austin, Texas):[94]

Materials/lf		$ 117
Erection/lf		24
Labor for shop fabricated T or L intersection		1000 ea.

The intersections are shop-assembled, then dismantled and shipped to the job site for final erection. Apparently, such intersections require little if any added stiffening.

The comments of the preceding section apply to the corrugated-steel structures herein as well, e.g., those on an installation manual that includes suggested lateral spacing minimums for parallel structures;[95] on sealing of seams; and that the subject of imposed (normal-use) loads on the fill over the structures is discussed below.

The Junior Underpass shapes can be used for connecting passageways between conventional box-like and/or corrugated-steel arch structures; they can also be used to connect to an emergency exit/ventilation outlet structure, which structure could use corrugated-steel pipe for a riser, as shown in Figures 1 and 3 of the above Congressional Testimony extract. However, the riser structure might be better fabricated as a R/C box structure, thus providing a flat vertical surface on which to hang a simple blast door.

Live Loads (Normal Use) on Buried C-S Structures. Certainly the corrugated-steel arch and conduit structures discussed in the preceding subsections, with a proven capability of withstanding at least one application of extremely high live loads even of short duration - 60 psi (8.64 kips/sf) for about 0.36 sec - would cause no concern when subjected to such loads as a passenger car or light pickup truck running on top of the 5-ft thick earth cover. Where a buried structure built to resist the combined effects of a nuclear weapon detonation is to be located under a parking lot and/or street, however, structural adequacy against typical automotive vehicle/truck wheel loads must be considered. And, of course, the typical worry of an engineer about someone overloading his structure can be related to this shelter situation as that of a large transit-mix truck turning around through a parking lot posted for automobile and/or light pickup limits!

Discussion of this problem[94] led to review of the currently-available (but under revision) handbook covering cover requirements and gage thickness under selected highway, railroad and airport wheel loadings.[98] An extract (Chapter 3, Structural Design, in its entirety) was kindly furnished to the author[94] based on information that the publication is currently out-of-print. Table HC-17, page 120, shows height-of-cover requirements for H20 live loads on C-S arch structures (rise-span ratios of 0.3 to 0.5) on unyielding foundations, 6"x2" corrugations, 26-ft span, to be 4 ft minimum and 18 ft maximum using 1 ga., not thinner. For 25-ft span, similar values are 4 ft and 17 ft using 3 ga., not thinner. Because of this apparent need for 1 ga. material in the 26-ft span, <u>if</u> an H20 loading is applied, the cost estimates in the arch subsection above include both 1 and 10 ga. arch structures.

Because of the considerable increase in cost, as between using 1 ga. instead of the test structure's 10 ga. C-S, a thorough review was made by the author of the structural design procedure[98(p.88-92)] currently used. After working example problems and working problems to spot-check various values in Table HC-17 just mentioned, the design procedure was applied to the tested structure's current counterpart, the 26'0" span by 11'10" rise, 10 ga. C-S arch structure, with the result that the structure was found to be adequate for an H20* live loading in all design steps, but with one non-design matter left requiring decision. Step 6 of the design procedure[98(p.91)] calls for checking of handling stiffness - in other words a check against construction erection difficulties. For this a flexibility factor FF is calculated, then weighed against the following: "Recommended maximum values of FF for ordinary installations: FF = 0.0433 for factory-made pipe with riveted, welded, or helical seams less than 120-in. diam.; and, FF = 0.0200 for field-assembled pipe with bolted seams and all sizes over 120-in. diam. Higher values can be used with special care or where experience has so proved." For the 10 ga. arch structure

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* For review, H20 loading shows a GVW of 20 tons, distributed 8 tons on each rear wheel and 2 tons on each front wheel of a vehicle with wheelbase of 14 ft and tread of 6 ft.

the design value for FF = 0.0415, It is recommended that the structure be used as designed, satisfying the design Step 6 through the fact that this is not an "ordinary" installation, by use of "special care" and, finally, because this is "where experience has so proved" (that a higher value than 0.0200 can be safely used). Finally, "field-assembled pipe with bolted seams..." is more difficult to erect and control in shape during backfilling, than would be a 170° arch erected on an unyielding foundation. In short, the matter is a construction erection problem, not one of structure safety after construction. Great care in backfilling and the availability of specifications therefor have been discussed above; a further suggestion has been made that a manufacturer's specially-qualified engineer be called for onsite (under the specifications) to advise/assist those having construction supervision and inspection responsibilities during all earthwork, especially backfilling and related soils testing and controls work.[94]

For the Junior Underpass and circular C-S structures discussed in the preceding subsection, Tables HC-5 and HC-15 (pages 110 and 118)[98] show, for 6"x2" corrugations/*10* ga./under *H20 loading*, minimum and maximun cover thicknesses of 1' and 20' or more, and 1' and 75', respectively, leaving little room for concern with live load on such structures.

Application Example. An EOC expansion of 5,460 sf is planned by the Division of Disaster Emergency Services, Texas Department of Public Safety, using three 26-ft span multiplate arch structures with junior underpass structures for connecting passageways; mention of this planning has been made above. Further details became available, after submission of the DRAFT report for technical review - extracts from Texas DES documents are provided below:

"Purpose:

> "To develop economically feasible means of providing "hardened" working space . . . (and) provide additional office and emergency operational space for DES, Communications and the Governor's Disaster Council . . . .

"Concept:

"1. Background

Historically, Federal, State, and local agencies have used the "brute force" approach to design of blast and radiation resistant structures. The Regional Federal Center at Denton and the State EOC at DPS headquarters, as well as NORAD headquarters in Colorado, are all examples of this highly expensive approach. Escalating costs and a gravely complex international situation add increasingly greater importance to a "better way" of providing the necessary facilities.

"2. Proposed Approach

Based on research by H. L. Murphy of Stanford Research Institute and the Priscilla test shots of Operation Plumbbob, it is proposed that approximately 5,460 square feet of floor space be added to the existing State EOC by burying three 70' x 26' standard "ARMCO" multiplate arch buildings under the east parking lot. These will have a minimum of 5' of ASHTO specification backfill and will be connected to each other and the existing building by use of "ARMCO" junior underpass manufactured of 10-gauge steel. Access would be through the space now utilized by the DES training staff (see Attachment #1).* This approach, according to the Plumbbob tests, would provide greater blast resistance than the original structure as well as providing adequate radiation and EMP protection."

* Copy of Attachment #1 not provided herein.

Preliminary Estimate August 2, 1976
Prototype "ARMCO STEELPLATE" Blast Resistant EOC Addition

Area	
5,460 sq. ft., 3 wings, 26' X 70'	
Earthwork	
Excavation - 9,000 cy @ $4.00	$ 36,000
Backfill - 3,000 cy @ $5.00 (select)	15,000
	$ 51,000
Structural	
Multiplate #102A15-24 - 210 lin. ft. @ $232.00	$ 48,720
Jr. Underpass - 50 lin. ft. @ $141.00	7,050
Bulk Heads - 6 @ $4,000.00	24,000
	$ 79,770
Foundation	
Beam and Slab - 100 cy @ $117.00	$ 11,700
Mechanical	
HVAC - 5,460 sq. ft. @ $1.80	$ 9,828
Electrical	12,558
Plumbing	5,197
	$ 27,583
Architectural	
Partitions - 3,600 sq. ft. @ $2.70	$ 9,720
Ceiling - 5,460 sq. ft. @ $1.22	6,662
Vinyl Flooring - 5,460 sq. ft. @ $ .52	2,840
	$ 19,222
Grand Total Construction	$189,275
A & E Fee @ 7%	13,250
Management (Building Comm.) @ 2%	3,786
Total Project	$206,311
Square Foot Cost	$ 38

I. Two-Way Slabs

This section concerns design of two-way slabs that are supported by stiff beams* of walls on all four sides.† Slab support conditions may be simple, partially fixed (e.g., framed into a torsionally stiff beam or wall) or fully fixed, with different combinations among the four edges of the slab.

Reinforcing steel is uniformly distributed across the slab, both ways (rather than being handled differently, as in column and middle strips[60,99]), because of the large elasto-plastic deflections contemplated in blast-resistant design. Another argument for uniform distribution of rebars across the slab is related to the universally used source of stiffness factors and moment equations for two-way R/C slab design. The source[2(Ref.8-6)] (Timoshenko 1940) clearly states that the data provided are based on (1) plates of an isotropic homogeneous material and (2) a Poisson's ratio of 0.3 (e.g., steel), neither of which criteria applies to R/C. To even approximately meet the first criterion, rebars should be uniformly distributed across the two-way slab. For the second criterion, the 0.3 ratio was retained inappropriately in some sources,[22,34] but was changed to 0.15 (appropriate for R/C) and associated data corrected in other sources,[2,33] which include one of the primary sources[2] used in our overall slanting guidance.[81(or 50-61-62-80)]

Stiff beams,* as used herein, are those meeting the following criterion:

$$\alpha_1 \ell_2/\ell_1 \geq 1 \qquad (6\text{-}57)$$

checked in a cross section through both the support beam and its adjacent slab(s) to its(their) centerline(s), and done for beam/slab combinations in both directions if the slab is not square (as measured center-center of support beams/walls); where:

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* Stiff enough to minimize their contribution to slab deflection; their stiffness is relative to the slab and not to beams in general, and their use (or use of walls) allows almost independent design of slabs and beams.[99]

† Design procedure is limited to slabs with length/width ratios of 2 or less (dimensions taken center-center of supporting beams/walls).

$\alpha_1 = I_b/I_s$ ($= E_{cb}I_b/E_{cs}I_s$ should be used if $E_{cb} \neq E_{cs}$)

ℓ_1 = length of span (center-center of supports) for cross section under design or review

ℓ_2 = length of span (center-center of supports) transverse to ℓ_1

I_b = moment of inertia about centroidal axis of beam gross section that includes (slab) flange equal on each side to the smaller of two widths: four times slab thickness, or the beam thickness extending below the slab.

I_s = moment of inertia about centroidal axis of slab gross section (i.e., I_s = [(slab thickness)^3/12] [slab width]; slab width equals ℓ_2, or half ℓ_2 if beam is at a discontinuous slab edge, using all of that width as if no beams were present).[99]

If the guidance provided under the Beam Design section above* is followed, it is likely that all designed support beams will readily meet the above criterion for stiff beams.

Support Beams Design. Preceding sections in the above referenced slanting guidance[81] provide detailed preliminary and final design procedures for one-way slabs and thus for beams; however, in these procedures all loadings are uniform over the length of the structural member. Design of support beams for two-way slabs, therefore, needs only to be corrected for its non-uniform loading in order to use the earlier design procedure for blast-resistant one-way slabs/beams. Referring to the earlier slanting guidance, in the Typical Designs section of Chapter 6, subsections A and B provide step-by-step design methods for simply supported and continuous one-way slabs, respectively. For discussion purposes leading to a support beam design procedure hereunder, symmetrical support restraints are assumed,[2] and subsection A just mentioned will be generally followed but cognizance of subsection B is expected of the reader as well: Step 1 applies generally, use of $\mu = 3$ being recommended

* Ref. 81 or 80, Chapter 6.

for two-way slab support beams. Step 2 requires a guess at a peak value of q for flexure; this resistance function peak value for q in flexure (often termed q_f) could be represented by solving Equation 6-1 for q (omitting use of M_u), but the result would be for a uniformly distributed load (the c at the right end of Equation 6-1 takes care of the beam support conditions, FF, PC or SS); for the support beams hereunder, the load is triangular for square two-way slabs and for the short sides of non-square, rectangular slabs, while the load is trapezoidal for the long sides of non-square rectangular slabs; q_f equations for such loadings are as follows:[2]

For beam supporting the short (or square) side of slab:

$$q_f = 10.8\ (p_e+p_c) f_{dy}\ (b/a)\ (d/L)^2 \tag{6-58}$$

where q_f is a uniform pressure over the (entire) surface of the slab, a is center-center distance between adjacent long beams (or just adjacent beams for a square slab), b is beam width, d is effective depth of beam, L is beam clear span, f_{dy} is dynamic (average) yield strength of rebars, and p_e and p_c are tensile reinforcing steel ratios (not percentages) at end(s) and mid-span, respectively (if p_e is varied a little at the two ends because of support conditions with somewhat different fixity, use the average of the two end values in Equation 6-58).

For beam supporting the long side of a two-way slab:

$$q_f = 7.2\ (p_e+p_c) f_{dy}\ (b/a)\ (d/L)^2\ [1/(1 - \alpha^2/3)] \tag{6-59}$$

where the terms are as previously defined, with α being the ratio of the short to long spans (center-center of supports) of the two-way slabs.

Equations 6-58 and 6-59 apply to interior beams only; they must be modified if the beams support only a single panel, i.e., on only one side of the beam.

As an alternative approach to design of the beams supporting the short (or square) side of a two-way slab, the following values were worked

out, where: q is the load (or resistance) per unit area; w is the peak load/unit length of beam, so w = aq;* and $\bar{w}$ is equivalent uniform load/unit length of beam:

	SS	FF(at ends)	FF(at center)
$\bar{w}$ (moment equivalence)	2w/3	-5w/8	3w/4
$\bar{w}$ (end shear equivalence)	w/2	w/2	

Therefore, assuming $q = \bar{w} / a$ permits using directly the final design procedures for SS and FF beams (one-way slabs) of subsections A and B mentioned above.

In either approach, the q found to be needed for flexure must be equalled or exceeded, as always, in checking for diagonal tension, pure shear and bond, as described in subsections A and B.[81]

Rebound steel may be justified in these support beams; however, consideration could be given to its omission, leaving rebound resistance to the two-way slab to be carried by the support beams.

Two-Way Slab Design. After examining the design approaches generally based on the current ACI code and normal loads, it was concluded that the design work was excessive for the purposes of blast-resistant design, and that an approach using reference 2 (pages 8-13 and 8-19) would be recommended for use herein:

1. Trilinear resistance functions appear for slabs fixed on two or more edges in three references cited herein;[22,33,34] of these three, however, only Biggs (1964)[33] has been corrected for the Poisson's ratio of 0.3 (for steel) used in the source document for all three references, i.e., Timoshenko (1940),[2(Ref.8-6)] to 0.15 (appropriate for R/C) as mentioned above, thus should be the preferred source if the designer feels

* Values in paragraph assume equal-sized slab on each side of support beam; if an edge beam supports a slab triangular tributary area on one side only, use a/2 in place of a in all of above. (Note: Project time was inadequate to work out similar values for trapezoidal loads on long support beams under rectangular two-way slabs; one approach is through use of the numerical methods introduced in a later section herein.)

impelled to use trilinear resistance functions (elastic, elasto-plastic and plastic; see Table 6.3, Chapter 11, Ref. 81). The purpose of such resistance functions is, of course, to attempt to refine the design somewhat over the bilinear function approach that follows.

2. Bilinear resistance functions are used for two-way slabs, whether simply supported or fixed on two or more edges, by simply ignoring the elasto-plastic phase of the resistance function described just above, i.e., the resistance function used simply extends the elastic phase line up to intersect the extended plastic phase line.[2] Elastic phase stiffness values may be taken from either of two sources, because both have been corrected in terms of Poissons's ratio, i.e., from 0.3 to 0.15.[2,33*] Location of the plastic phase line (yield resistance, considered constant) is discussed below.

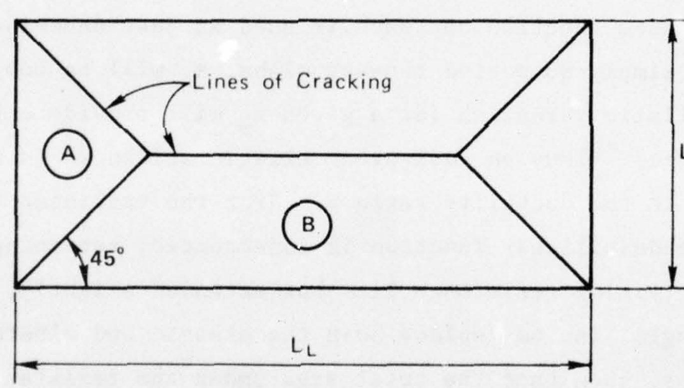
3. The ductility ratio μ ($=x_m/x_e$), commonly used as a yardstick of allowable or design, maximum resistance, poses some problems when the bilinear resistance function approach is used as just described; i.e., for other than simply supported two-way slabs, x_e will be too small to serve as a realistic yardstick (or a given x_m will provide a μ that is incorrectly large). Thus an equivalent elastic stiffness is needed for calculating x_e in the ductility ratio μ.. [For the trilinear resistance function, a pseudo-bilinear function is constructed, retaining the horizontal plastic (yield) resistance line but extended slightly, and constructing a single line to replace both the elastic and elasto-plastic resistance lines, such that the total area under the resistance function is unchanged for any x_m falling out on the original plastic resistance line. Stated another way, the equivalent x_e for a trilinear resistance function is a compromise between an x_e found by simply extending both the elastic and plastic resistance lines until they meet, and an x_e found from the intersection of the elasto-plastic and plastic resistance lines.] As alternatives to an equivalent elastic stiffness for

---

* But units differ in the two source tables. Again, care must be exercised that units are consistent, e.g., especially in the equation of motion $p(t) - q(x) = ma$ (use unit values OR total values, for the member under design).

calculating x_e when using a bilinear resistance function approach to design of a two-way slab supported on two or more sides: one can estimate a stiffness value; go through a series of intricate calculations so time-consuming as to be of questionable worth; or simply consider that the x_e obtained from use of only the extension of elastic and plastic resistance function lines is actually low and increase, judgementally, the μ considered appropriate for the design task.

4. For the plastic phase (constant yield resistance) line of our bilinear resistance function for two-way slab design, whether simply supported or with two or more fixed edges: (The reader's attention is invited to Reference 2, pages 8-13 to 8-19 and Figure 9-8 on page 9-22; every effort has been made to make complete the following material, but collateral reading in the referenced material may well be helpful, nevertheless.) Envisioning a rectangular (two-way) slab with assumed yield lines or a crack pattern as shown:[2(Fig.8-4)]



ASSUMED CRACK PATTERN FOR TWO-WAY SLABS

the flexural yield resistance of segment A is:[2]

$$q_A = 21.6\ (p_{Le} + p_{Lc})\ f_{dy}\ (d/L_s)^2 \qquad (6\text{-}60)$$

and of segment B is:[2]

$$q_B = 21.6\ (p_{se} + p_{sc})\ f_{dy}\ (d/L_s)^2\ [1/(3 - 2\alpha)] \qquad (6\text{-}61)$$

where parameters are as defined before and subscripts on the p's indicate the direction and position of the reinforcing steel.

If the assumed yield/crack lines are the correct ones, then $q_A = q_B$ which leads to

$$[1/(3 - 2\alpha)] = [(p_{Le} + p_{Lc}) \; / \; (p_{se} + p_{sc}) = C, \text{ for convenience}] \qquad (6\text{-}62)$$

Even though the definite steel relationship, for a given α, as shown by Equation 6-62 may not be precisely met, meaning q_A may not equal q_B closely, an estimate of the slab's flexural yield resistance can be obtained as an average of q_A and q_B, weighted on the basis of the areas of the two segments; the resulting yield resistance is:[2]

$$q_f = 10.8 \; (p_{se} + p_{sc}) \; f_{dy} \; (d/L_s)^2 \; [(2-\alpha)/(3-2\alpha) + \alpha C] \qquad (6\text{-}63)$$

where C is as shown in Equation 6-62.

Results of this approach may in some instances overestimate the slab resistance, but generally not enough to warrant redesign by more refined yield line theory application; edge panels, however, or other cases with unsymmetrical support conditions, should be checked for adequacy.[2]

By comparing Equation 6-63 with a similar one for a one-way slab, the following relationship results:[2]

$$W = 1 + \alpha[1/(6 - 4\alpha) + 1.5 \; C] \qquad (6\text{-}64)$$

where C is as defined by Equation 6-62 and the constant W is a conversion factor that relates the resistance of a two-way slab numerically to that of a one-way slab spanning the short dimension of the two-way slab; that is, the maximum pressure that a two-way slab can resist is that of a one-way slab (with span and rebars corresponding to the short dimension of the two-way slab) times the conversion factor W.

As an aid in getting design started, Equations 6-62 and 6-64 may be combined to show than an ideal value for W might be

$$W = 1 + \alpha \; [1/(6 - 4\alpha) + 1.5/(3 - 2\alpha)] \qquad (6\text{-}65)$$

5. To summarize the flexural phase of two-way slab design, discussed in the preceding 4 paragraphs, particularly as it relates to design of

one-way slabs, design procedures for which are completely described in subsections A and B:[81]

a. A peak value q must still be assumed for the (bilinear) elasto-plastic resistance function (see Step 2 of the one-way slab design procedures).[81] For a simplified (or first trial) case for illustration, let $\mu = 8$ for the two-way slab and use a step pulse $[p_m/q = 1 - 1/2\mu]$; one obtains a value for q (or q_f if preferred) of $q = p_m(16/15)$, or = 16 psi for $p_m = 15$ psi. For later trials, a Beta-method solution(s) may be appropriate. Assuming a two-way slab with center-center support dimensions of 16 by 20 ft, $\alpha = 0.8$ and an ideal value of W would be 2.143 (Equation 6-65). Thus q (or q_f) for a one-way slab in the short direction (16 ft, or a clear span of perhaps 14.5 ft, guessing at 1'6" wide support beams) should be designed for $q_{fs} = qW = 7.47$ psi. It is urged that q_{fs} be increased somewhat above this result of an ideal W calculation, because the longitudinal rebars will probably have the short way bars outside (top and bottom) of the long way bars, thus the latter will have a less effective moment arm, even though all four steel ratios (p with various subscripts) and Equation 6-62 are fully compatible. It is recommended that no p value be larger than about 0.015 (rather than the peak 0.02 recommended for one-way slabs) to make yield line behavior more likely. Further, in the absence of any real guidance on the matter,[2] it is recommended that rebound steel, if used, be at 0.25 times related tensile steel ratios (prime marks may be used to designate this steel, e.g., p_{Lc} and p'_{Lc} etc.).

b. For the fundamental period of vibration T of a two-way slab, an approximation for one simply supported on rigid[2(Ref.8-7)] or stiff beams is available:[2]

$$T = 5.3 \; (w / Kg)^{0.5}, \text{sec.} \tag{6-66}$$

where K is the stiffness per unit area of slab (at center), with data sources already described, and w is the weight per unit area of slab. The corresponding equation for fixed supports differs only in that the constant is 4.5 rather than the 5.3 above. For other support combinations, a reference is available.[2(Ref.8-8)]

c. With the short direction of the two-way slab designed for flexure, using the one-way slab design approach of subsections A and B,[81] use of Equation 6-62 provides the long direction slab steel ratios, which can then be used, again with the one-way slab design approach, culminating in the completed (first trial at least) flexural design of the two-way slab.

6. Shear and diagonal tension resistance of a two-way slab is taken as $(2/3)(1 + \alpha)$ times that for a one-way slab spanning in the short direction, when α is 1/2 or more[2] (which is a stated limitation for the entire two-way slab design section herein). This information may be used in conjunction with the one-way slab design procedure cited above, to complete design steps for diagonal tension, pure shear and bond.

7. Load-mass factors, if desired for use, are included in Chapter 11, Ref. 81.

J. Flat Slabs

Design of flat slabs to resist blast loads is not included in our principal source document.[2] An often cited source herein, however, gives a bilinear resistance function approach to such design, but limited to transformation factors and other such data for square, interior, uniform load, flat slabs.[33] Tabular information covers column capitals that are square and can vary in size from 5% to 25% of the column spacing.

The design approach follows similar steps to those used so frequently herein, starting with one-way slabs, simply supported, that the procedure described, even though brief, should be understandable and useful to the designer who has familiarized himself with the design procedures for other structural members described herein.

Miscellaneous Design Techniques

A. Numerical Methods - Beams

Handbooks provide many formulas for beams under various support conditions, but most are applicable only to prismatic beams in calculating stiffness and deflections, for example.[3,19] Numerical methods[100] become very useful to the designer dealing with blast loadings, when faced with such things as tapered steel sections, or even normal-design reinforced concrete members wherein rebars are often cut off are various points in the span. For the R/C members, moment of inertia I is most often taken as the average of the gross section I and the transformed section I, meaning that the member is non-prismatic. Further, ability to handle non-prismatic members can be coupled with learning a numerical method for calculating the maximum flexural and axial stresses in a beam-column, whether or not the loading system is a complicated one. This section is thur a necessary prelude to the following one that deals with beam-columns.

This section deals with lateral loads on a beam (or section of a slab); oblique loads can be resolved into lateral and axial loads, then dealt with as described in the next section, as can eccentric axial loads and direct moment loads.

Distributed lateral loads can be treated in two types, those varying linearly and non-linearly over a section of the beam; Figure 6-14 shows formulas for converting such distributed loads into concentrated loads the use of which will lead to values needed by the structural designer, i.e., shear, moment, end and chord slope, and deflection, each at selected points termed herein "node points." The linearly-varying, or trapezoidal, loading can vary in spacing at any or all node points (or simply "nodes"); if linear over more than one node spacing h - say over points a,b,c - the respective concentrated loads would be (2a+b), (a+4b+c) and (2c+b), <u>all</u> multiplied by h/6 as a common multiplier carried at the right side of the calculation sheet for convenience.

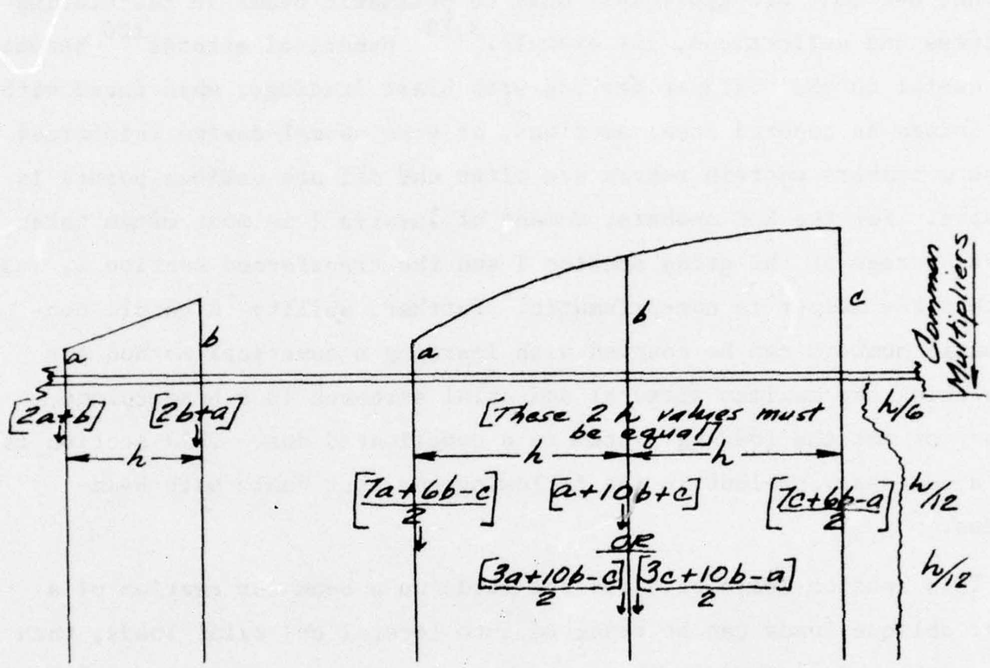


FIGURE 6-14 EQUIVALENT CONCENTRATED LOADS FOR DISTRIBUTED LOADS

The non-linearly-varying, or parabolic, loading is so-called for convenience and because a parabola passed through three points, uniformly spaced, is used for obtaining equivalent concentrated loads in this case; Figure 6-14 shows how to calculate end values, central value, and both forward and backward portions of the central value. For a parabolic (or curved) loading extending over more than two EQUAL node spacings, the central value formula would be used as often as needed to deal with all central values. It is important to emphasize, however, that should any break in the curve intervene (for such things as a concentrated load superimposed on the distributed load, or a variation in I (or even E which can be dealt with in the same manner as a varying I)), then each curved section of the loading must be broken into nodes so that each such section has at least two equal node spacings. Examples to follow should help to make this matter clear. The common multiplier for the parabolic loading is h/12.

Downward loads are taken as negative in order that moments will be positive at such places, for example, as the central portion of a simply-supported beam. Deflections are obtained through use of the conjugate beam method; for review, the method first goes through the usual calculations of loads, reactions, shears and moments, then goes through a similar set of calculations using the M/EI-diagram as the loading on the beam, which calculations yield end and chord slopes, then deflections. M/EI-diagram "loadings" are also taken as negative when downward, thus leading to deflections where positive values mean downward. Unfortunately, this sign convention provides end and chord slopes that are reversed in sign from the usual convention for slope.

Figure 6-15 shows a distributed load converted to two concentrated loads by using the trapezoidal formulas, then calculation of trial shear values (just guess at left reaction or first node space value) and moments, then application of a line of moment correction values (varying linearly across the span - in reality only shifting the base line) to bring the right support moment to zero, then finally calculation of the corrected moments and, if desired, the corrected shears and the reactions.

$h = L/4$

Load	p	0	0	−1	0	0		w
			[2a+b]	[a+2b]				
Conc. load	$\bar{p}$	0	−1	−2	0	0		$w\left[h/6\right]$
Trial shear	v_t	0	0	−1	−3	−3	−3	"
Trial moment	M_t	0	0	−1	−4	−7		$w\left[\frac{h}{6}\right]h = wh^2/6$
Correction "	M_c	0	7/4	7/2	21/4	+7		
Moment	M	0	7	10	5	0		$\frac{1}{4}\left[wh^2/6\right] = wh^2/24 = wL^2/384$
Shear	v	7	7	3	−5	−5	−5	$wh/_{6\times4} = wL/_{24\times4} = wL/96$
Reactions		7				5		$wL/96$

<u>PROOF:</u>

Taking moments about right end; get reactions @ supports:

$$R_L L = \frac{wL}{8}\left[\frac{L}{2} + \frac{L}{12}\right] = \frac{wL}{8} \times \frac{7L}{12} = \frac{7wL^2}{96}$$

$$R_L = 7wL/96$$

$$R_R = \frac{7}{96}wL + \frac{wL}{8} = \frac{5}{96}wL$$

Moment @ mid-span (taking moments to left of section):

$$M = R_L\frac{L}{2} - \frac{wL}{8} \times \frac{L}{12} = \frac{7wL}{96} \times \frac{L}{2} - \frac{wL^2}{96} = \frac{10}{384}wL^2$$

Moment @ quarter point (ditto):

$$M = R_L \times \frac{L}{4} = \frac{7}{96}wL \times \frac{L}{4} = \frac{7}{384}wL^2$$

FIGURE 6-15 BEAM WITH TRIANGULAR LOAD OVER PART SPAN

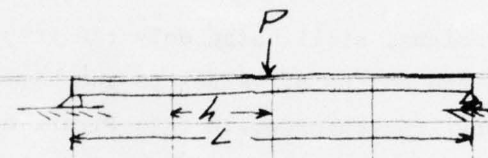
Figure 6-16 shows the calculations involved in carrying a single concentrated load through to moments and deflections. Note that such a load will yield a straight line (or trapezoidal) -M/EI loading for the conjugate beam, thus the trapezoidal formulas (Figure 6-14) are used for concentrating the -M/EI loading in this case.

Both Figures 6-15 and 6-16 show "proofs" that the user can apply if desired.

Figure 6-17 shows two problems, still using only the trapezoidal concentration formulas. Note the shifts of values to the common multipliers, solely for calculational convenience, in this Figure and in Figures 6-15 and 6-16.

Figure 6-18 shows a simple distributed load problem, which the user can check against handbook formulas.[3,19] It serves, however, to introduce use of the parabolic concentration formulas. Note that the trapezoidal formulas are used to get equivalent concentrated loads, for the shear and moment calculations, then the parabolic formulas are used to concentrate the distributed -M/EI loading on the conjugate beam, leading to slopes and deflections. Note that end shear and end slope, each on the left side of the tabulation, need not be first "guessed" (i.e., a trial value used) as it was for end shear in Figure 6-15, but may be quickly calculated due to symmetry of loading (as it was in Figure 6-16).

Figure 6-19, although symetrically loaded, adds the complications of a concentrated center load to the problem of Figure 6-18. Figure 6-19 shows the combining of concentrated loads, from those obtained through use of the concentration formulas applied to distributed loads, plus any loads that were actual concentrated loads in the original problem statement. Shears and moments readily follow, once the combined concentrated loads are available. Moving to the concentration of the -M/EI loading on the conjugate beam, however, shows the calculation of separate values, backward and forward, at the "cusp" caused by the original concentrated load of 12wh; the two separate values are then simply added, totalling -858. For comparison, the Figure shows the value (lined out) calculated



$\bar{P}$	0	0	-2	0	0		$P/2$
v	1	1	1	-1	-1	-1	
M	0	1	2	1	0		$Ph/2$
$\alpha = -\frac{M}{EI}$	0	-1	-2	-1	0		$Ph/2EI$
$\bar{\alpha}$	-1	-6	-10	-6	-1		$Ph^2/12EI$
ϕ	12	11	5	-5	-11	-12	"
y	0	11	16	11	0		$Ph^3/12EI$

Compare with handbook values:

Midspan moment

$$2Ph/2 = \frac{2P}{2} \times \frac{L}{4} = 2PL/8 = \frac{PL}{4}$$

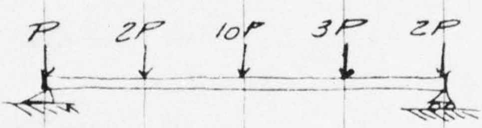
Midspan deflection

$$\frac{16Ph^3}{12EI} = \frac{4}{3}\frac{P}{EI}\left[\frac{L}{4}\right]^3 = \frac{PL^3}{48EI}$$

FIGURE 6-16 BEAM WITH CONCENTRATED LOAD AT MID-SPAN

$h = L/4$

p		0		-0.5		-1		-0.5		0		w
p		0		-1		-2		-1		0		$w/2$
		[2a+b]		[a+4b+c]		[b+4c+d]		[c+4d+e]		[d+2e]		
$\bar{P}$		-1		-6		-10		-6		-1		$wh/12 = wL/48$
v	12		11		5		-5		-11		-12	"
M		0		11		16		11		0		$wh^2/12 = wL^2/192$



$\bar{P}$		-1		-2		-10		-3		-2		P
v_t	9		8		6		-4		-7		-9	P
M_t		0		8		14		10		3		Ph
M_c		0		$-3/4$		$-3/2$		$-9/4$		-3		"
M		0		$7\frac{1}{4}$		$12\frac{1}{2}$		$7\frac{3}{4}$		0		"
v	$8\frac{1}{4}$		$7\frac{1}{4}$		$+5\frac{1}{4}$		$-4\frac{3}{4}$		$-7\frac{3}{4}$		$-9\frac{3}{4}$	P
M		0		29		50		31		0		$Ph/4$
$\alpha = -\frac{M}{EI}$		0		-29		-50		-31		0		$Ph/4EI$
$\bar{\alpha}$		-29		-166		-260		-174		-31		$Ph^2/24EI$
Slope ϕ_t	300		271		105		-155		-329		-360	"
Defl. y_t		0		271		376		221		-108		$Ph^3/24EI$
y_0		0		27		54		81		108		"
y		0		298		430		302		0		"
Slope ϕ	327		298		132		-128		-302		-333	$Ph^2/24EI$

FIGURE 6-17 BEAMS WITH TRIANGULAR LOAD AND WITH CONCENTRATED LOADS

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MAXIMIZING PROTECTION IN NEW EOCS FROM NUCLEAR BLAST AND RELATE--ETC(U)
SEP 76 H L MURPHY, J E BECK DCPA01-76-C-0161

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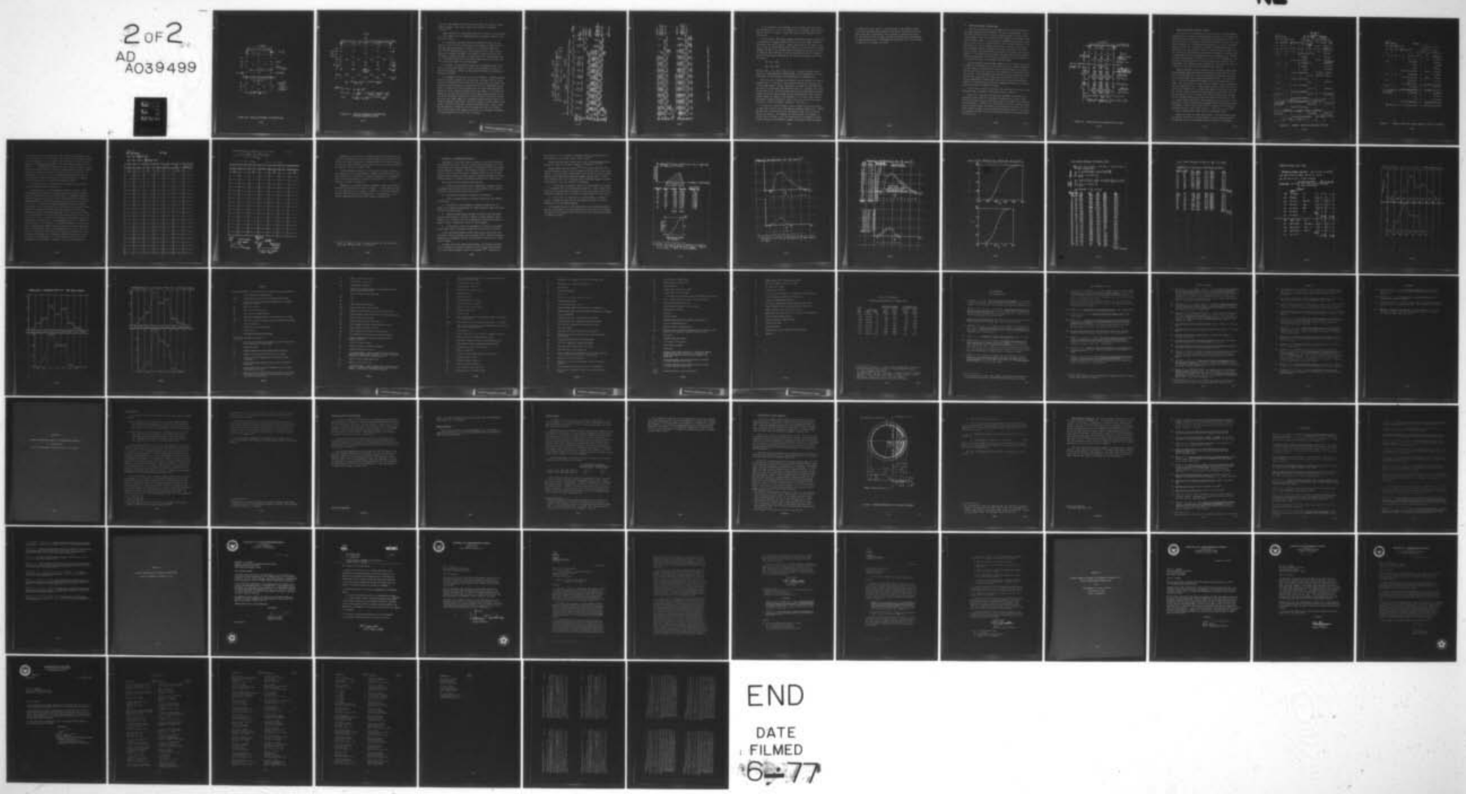

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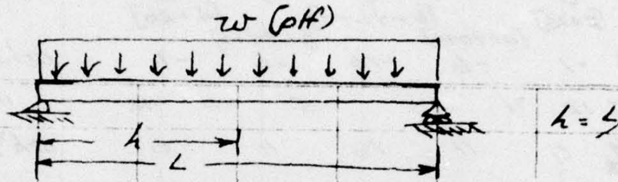


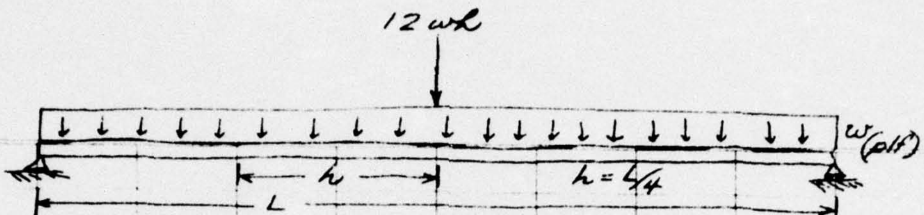
P	-1		-1		-1	w
$\bar{P}$	-3		-6		-3	$wh/6$
V	6	3		-3	-6	"
M	0		3		0	$wh^2/6 = wL^2/24$

$$M_{max} = 3\,wL^2/24 = wL^2/8$$

$\alpha = -\frac{M}{EI}$	0		-3		0	$wh^2/6EI$
	$\left[\frac{7a+6b-c}{2}\right]$		$\underbrace{\left[\frac{3a+10b-c}{2}\right]\left[\frac{-a+10b+3c}{2}\right]}_{[a+10b+c]}$		$\left[\frac{7c+6b-a}{2}\right]$	
	"				"	
$\bar{\alpha}$	-9		-30		-9	$\frac{h}{12}\left[\frac{wh^2}{6EI}\right]$
ϕ	24	15		-15	-24	$wh^3/72EI$
y	0		15		0	$wh^4/72EI$

$$y_c = \frac{15}{72}\,\frac{wh^4}{EI} = \frac{5}{384}\,wL^4$$

FIGURE 6-18 BEAM WITH UNIFORMLY DISTRIBUTED LOAD



p	-1		-1		-1		-1		-1	w
Unif. $\bar{p}$	-3		-6		-6		-6		-3	$\frac{wh}{6}$
Conc. $\bar{p}$					-72					"
Total $\bar{p}$	-3		-6		-78		-6		-3	"
v	48	45		39		-39		-45	-48	"
M	0		45		84		45		0	$\frac{wh^2}{6}$
$\alpha = -\frac{M}{EI}$	0		-45		-84		-45		0	$\frac{wh^2}{6EI}$
$\bar{\alpha}$	-93		-534		$\cancel{-930}$ -429 -429 -858		-534		-93	$\frac{wh^3}{72EI}$
ϕ	1056	963		429		-429		-963		"
y	0		963		1392		963		0	$\frac{wh^4}{72EI}$

$$y_c = 1392 \times \frac{w}{72EI}\left[\frac{L}{4}\right]^4 = 0.075521\,\frac{wL^4}{EI}$$

<u>Check:</u>

Unif. load: $y_c = \frac{5}{384}\,\frac{wL^4}{EI}$

Conc. load: $y_c = \frac{PL^3}{48EI} = 12wh\left[\frac{L^3}{48EI}\right] = \frac{3wL^4}{48EI} = \frac{wL^4}{16EI}$

Total: $y_c = \left[\frac{5}{384} + \frac{1}{16}\right]\frac{wL^4}{EI} = 0.075521\,\frac{wL^4}{EI}$

FIGURE 6-19 BEAM WITH UNIFORMLY DISTRIBUTED AND MID-SPAN CONCENTRATED LOADS

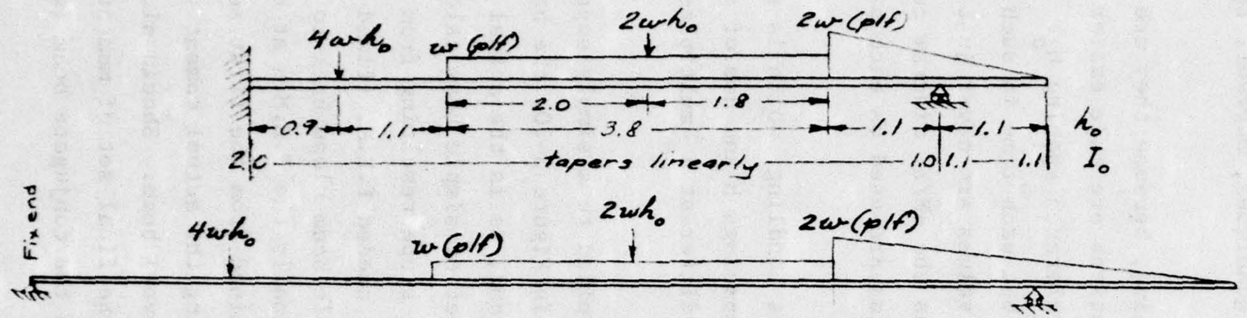
with the "cusp" ignored, which action would result in incorrect slopes and deflections. (The "check" shown comes from use of handbook formulas.[3,19])

Figure 6-20 uses a problem whose real-life occurrence is most unlikely. The problem serves to illustrate several techniques, however, that should be useful:

- Varying node spacings h and their handling, because they are likely to occur in actual applications; calculations are made easier by reducing each node spacing to a multiple of a reference spacing h_o. Note that the multiples are used where needed, but each time in such a way that two adjacent multiples with different values are never just "averaged"; instead the change is treated as was the -M/EI diagram cusp, i.e., backward and forward concentration formulas are used on each side of the node point where the spacing changes.

- Varying I (a non-prismatic beam) and its handling, which is similar to that just described for a mix of node spacings h and use of a reference spacing h_o. Again, any averaging of different I_o multiples is studiously avoided.

- End moments, fully-fixed or not, are applied to a simply supported beam for purposes of making the calculations. In Figure 6-20, the beam used for calculations is not fixed at the left end, as is the actual beam. Instead the left end slope is obtained from a set of simple beam calculations; a separate set of calculations shows the slope resulting from the application of an assumed end moment alone; the needed F.E.M. (fixed end moment) at the left end to bring the first simple beam slope back to zero is readily calculated (variation is linear); finally the F.E.M.s at each node point are simply added to the moments obtained from the first set of (simply supported) calculations, the result being the actual moment values at each node point of the real (propped cantilever) beam. Should slopes and deflections be desired for the real beam, the final set of moment values can be used; -M/EI loading is applied to the conjugate beam (which is simply supported at the left end, of course).



L = span
$L = 6.9\,h_o$

	Values	Units
	0.45 0.45 0.55 0.55 1.0 1.0 0.9 0.9 0.55 0.55 0.55 0.55	h_o
	2.0 1.93 1.87 1.79 1.71 1.57 1.42 1.29 1.16 1.08 1.0 1.1 1.1 1.1	I_o
Distr. p	0 0 0 0 -1 -1 -1 -1 -1 -2 -1.5 -1 -0.5 0	w
Distr. $\bar{p}/h$	0 0 0 0 -3 -6 -3 -3 -6 -3 -5.5 -9 1 -3 -0.5	$w/6$
" $\bar{p}$	1 0 0 0 0 -3 -6 -3 -2.7 -5.4 -2.7 -3.025 -4.95 1 -1.65 -0.275	$wh_o/6$
Corr. $\bar{p}$	1 -24 -12	"
$\Sigma\,\bar{p}$	1 0 -24000 0 -3000 -6000 -17700 -5400 -5725 -4950 1 -1650 -275	$wh_o/6000$
v	1925 275 0	"
vh	1059 151 0	$wh_o^2/6000$
M	-1210 -151 0	"
v_{trial}	33000 33000 9000 9000 6000 0 -17700 -23100 -28825 -33775	$wh_o/6000$
$v_t h$	14850 14850 4950 4950 6000 0 -15930 -20790 -15854 -18576	$wh_o^2/6000$
M_t	0 14850 29700 34650 39600 45600 45600 29670 8880 -6974 -25550	"
$M_{corr.}$	0 1587 3175 5115 7055 10583 14110 17285 20460 22400 24340	"
M_{ss}	0 16437 32875 39765 46655 56183 59710 46955 29340 15426 -1210 -151 0	"
α	0 -8517 -17580 -22215 -27284 -35785 -42049 -36399 -25293 -14283 +1210 +1100 137 0	$wh_o^2/6000\,EI_o$
$\bar{\alpha}/h$	-1676 -10275 -8708 -11453 -26701 -15335 -18182 -42718 -24088 -24372 -43133 -17670 -13198 -16691 -2597 426 247 -14	$wh_o^2/(600\,EI_o \times 12)$
$\bar{\alpha}$	-754 -4624 -3919 -6299 -14686 -8434 -18182 -42718 -24088 -21935 -38820 -15903 -7259 -9180 -1194 136 -8	$wh_o^3/7200\,EI_o$
ϕ_t	100000 99246 94622 84404 69718 43102 384 -45639 -84459 -107621 -116801 -117995 -117859	"
$\phi_t h$	44661 42580 46422 38345 43102 384 -41075 -76013 -59192 -64241 -64897 -64822	$wh_o^4/7200\,EI_o$
y_t	0 44661 87241 133663 172008 215110 215494 174419 98406 39214 -25027 -89924 -154746	"
y_c	0 1632 25027	"
y_{ss}	0 46293 0	"
ϕh	46293	"
ϕ	103627 102873	$wh_o^3/7200\,EI_o$

M_{end}	-69000 ← [Trial end moment, applied as only load on (conjugate) beam]													$wh_0^2/6000$
M	-69000	-64500	-60000	-54500	-49000	-39000	-29000	-20000	-11000	-5500	0	0	0	"
α	34500	33420	32086	30447	28655	24841	20423	15504	9483	5093	0	0	0	$wh_0^2/6000EI_0$
α/h	20497	40079	19531 18931	36522	17559 16460	29749	13168 11325	18494	6949 4847	6044	1054			$wh_0^2/7200EI_0$
$\bar{\alpha}$	9224	18236	8789 10412	20087	9657 16460	29749	13168 10193	16645	6254 2666	3323	580			$wh_0^3/7200EI_0$
ϕ_t	-100000	-90776	-72740	-53539	-33452	-7335	22414	45775	62420	71340	74663	75243	75243	"
$\phi_t h$		-40849	-32733	-29446	-18399	-7335	22414	41198	56178	39237	41065	41384	41384	$wh_0^4/7200EI_0$
y_t	0	-40849	-73582	-103028	-121427	-128762	-106348	-65150	-8972	30265	71330	112714	154098	"
y_c	0	-4652									-71330			"
y	0	-45501									0			"
ϕh	-45501													
ϕ	-110337	-101113												

F.E.M. = -69000 (103627 ÷ 110337) = -64804

M_{ss}	0	16437	32875	39765	46655	56183	59710	46955	29340	15426	-1210	-151	0	$wh_0^2/6000$
M_{FEM}	-64804	-60578	-56351	-51186	-46020	-36628	-27236	-18784	-10331	-5166	0	0	0	"
ΣM	-64804	-44141	-23476	-11421	635	19555	32474	28171	19009	10260	-1210	-151	0	
α	32402	22871	12554	6380	-371	-12455	-22869	-21838	-16387	-9500	1210 1100	137	0	$wh_0^2/6000EI_0$
α/h	17574	27366	9635 6326	7598	1156 -2723	-14779	-11722 -13736	-25764	-11443 -8646	-11018	-1607 426	247	-14	$wh_0^2/7200EI_0$
$\bar{\alpha}$	7908	12315	4336 3479	4179	636 -2723	-14779	-11722 -12363	-23188	-10029 -4755	-6060	-884 234	136	-8	$wh_0^3/7200EI_0$
ϕ_t	0	7908	20223	28038	32217	30130	15351	-8734	-31922	-46706	-52766	-53416	-53280	-53288 "
$\phi_t h$	0	3559	9100	15421	17719	30130	15351	-7861	-28730	-25688	-29021	-29379	-29304	$wh_0^4/7200EI_0$
y_t	0	3559	12659	28080	45799	75929	91280	83419	54689	29001	-20	-29399	-58703	"
y_c	0	1	3	4	6	9	12	14	17	18	20	22	23	"
y	0	3560	12662	28084	45805	75938	91292	83433	54706	29019	0	-29377	-58680	"

FIGURE 6-20 BEAM WITH FIXED END, MIXED LOADS, AND VARYING I

• The treatment of an overhang, as at the right end of the beam; here moment goes to zero at the extreme end of the member, but deflection goes to zero at the support. Note that right-to-left calculations use subtraction.

A non-prismatic beam fixed at both ends requires separate application calculations of a trial end moment at each end of the simply supported equivalent beam, say M_L and M_R. Related end slopes can be termed ϕ_L and ϕ_R for those resulting from M_L; and ϕ'_L and ϕ'_R for those resulting from M_R. Using $\bar{\phi}_L$ and $\bar{\phi}_R$ for the required slope corrections at the ends, in order to bring the end slopes back to zero as was done for one end in Figure 6-19, two simultaneous equations in two unknowns (constants a and b) may be written:

$$\bar{\phi}_L = a\phi_L + b\phi'_L$$

$$\bar{\phi}_R = a\phi_R + b\phi'_R$$

Where $(F.E.M.)_L = aM_L$ and $(F.E.M.)_R = bM_R$. The same procedure must be used for an unsymmetrically loaded prismatic beam (specifically, the procedure must be used whenever the -M/EI-diagram is unsymmetrical).

There are many techniques not discussed herein, because they are not needed as part of this set of early steps prerequisite to the next section on beam-columns. However, additional techniques are available from the two sources mentioned under Reference 100; e.g., stiffness and carry-over factors can be quickly obtained, equivalent single-degree-of-freedom systems calculated, and problems of beams extending over three supports solved (remove one support, find deflection at its point, then calculate the upward "loading" required to restore that point to zero deflection, which is of course the support reaction at that point).

To close this section, mention should be made of one further point in connection with use of the concentration formulas, Figure 6-14. Should the user come to some point in his calculations where he is uncertain whether the loading - for example, the -M/EI diagram - is straight or curved (that is, whether to use the trapezoidal or the parabolic concentration formulas), the parabolic formulas can always be used, providing

of course that every (smoothly curved) section of the loading consists of at least two equal node spacings. This latter proviso may double the work of the user, unnecessarily if the loading is actually not curved but is treated as such; it might be better to either sketch the loading, or think through a line of reasoning that should lead to a correct answer on whether it is straight or curved.

B. Numerical Methods - Beam-Columns

Once the techniques of the preceding section on numerical methods for beam problems is well understood, the step to beam-columns is easy: The loads of whatever kind - lateral, oblique, axial, eccentric axial, or pure moment - must be converted to some combination of lateral, axial and pure moment loads. It is convenient, although not absolutely necessary, to first solve the beam problem at least through to moments at the node points, if not on through to deflections, using only the lateral and pure moment load(s); the moments can then be combined with the moments caused by each node point's eccentricity with respect to the axial load(s). If the deflections due only to lateral loads and pure moments have been calculated, they are helpful in making the first assumption as to the deflected shape of the member under all loads.

With an assumed deflected shape, moments due to an axial load(s) can be added to the moments due to other loads to get the combined moments at all node points; calculations can then be carried through to the deflections at each node point, which are then compared with the assumed deflection values. If the comparison shows results that are sufficiently close for the user's purposes, the results can be considered final, and the various combinations of moment and axial load at points along the beam column can be appropriately handled in designing the member (interaction equations, tables or diagrams are used).

If the results are not considered to be sufficiently accurate, a new deflected shape is assumed, and the whole task is repeated.

Figure 6-21 illustrates the numerical technique, even though only lateral and axial loads are included; the purpose was to focus on the iterative procedure, but all variations (such as in Figure 6-20 or others) can be included. In Figure 6-21, deflections were first calculated using only the lateral loads, from which a very lucky guess was made as to the final deflected shape; a second iteration was made, however, to illustrate the technique and show that the calculations converge on improved answers with each cycle.

P	-1		-1		-1		-1		-1	w
$\bar{P}$	-3		-6		-6		-6		-3	$wh/6$
v		9		3		-3		-9		"
M (dist. load)	0		9		12		9		0	$wh^2/6 = wL^2/96$
$\alpha = -M/EI$	0		-9		-12		-9		0	$wh^2/6EI$
$\bar{\alpha}$	/		-102		-138		-102		/	$wh^3/72EI$
ϕ		171		69		-69		-171		"
y	0		171		240		171		0	$wh^4/72EI = a$

Assume deflected shape with axial load P included:

$\left[\frac{x}{171}=\frac{300}{240};\ x=214\right]$

y_a	0		214		300 (assumed)		214		0	a
M(P)	0		214		300		214		0	$Pa = \boxed{\frac{12EI}{h^2}\times\frac{wh^4}{72EI}\times\frac{1}{100} = wh^2/6\times 1/100}$
M(dist)	0		900		1200		900		0	$wh^2/600$
M	0		1114		1500		1114		0	"
$\alpha\ [=-M/EI]$	0		-1114		-1500		-1114		0	$wh^2/600EI$
$\bar{\alpha}$	/		-12640		-17228		-12640		/	$wh^3/7200EI$
ϕ		21254		8614		-8614		-21254		"
y	0		21254		29868		21254		0	$wh^4/7200EI$
y_a/y	0		1.007		1.004		1.007		0	/

y_a	0		213		299		213		0	a
M(P)	0		213		299		213		0	$Pa = wh^2/600$
M(dist)	0		900		1200		900		0	"
M	0		1113		1499		1113		0	"
α	0		-1113		-1499		-1113		0	$wh^2/600EI$
$\bar{\alpha}$	/		-12629		-17216		-12629		/	$wh^3/7200EI$
ϕ		21237		8608		-8608		-21237		"
y	0		21237		29845		21237		0	$wh^4/7200EI$
y_a/y	0		1.0008		1.0008		1.0008		0	/

$$M_c \text{ (center)} = 1499\, wh^2/600 = \frac{1499}{600} w\left(\frac{L}{4}\right)^2 = 0.156\, wL^2$$

$$y_c = \frac{29845\, wh^4}{7200\, EI} = \frac{29845}{7200}\times\frac{w}{EI}\left(\frac{L}{4}\right)^4 = 0.0162\, wL^4/EI$$

FIGURE 6-21 BEAM-COLUMN WITH UNIFORM AND AXIAL LOADS

C. Numerical Methods - Newmark β Method

The solution of the equations of motion for even a single-degree-of-freedom system can readily be mathematically difficult if not impossible, depending on the complexity of the loading and resistance functions. To meet this problem, the Newmark β Method was developed[21] and has been used, either directly or in a modification developed by J. E. Beck, throughout Chapter 6 of Ref. 81. The method is capable of handling any shape of loading function and resistance function, although load, mass and resistance factors for transforming a given structural member or assembly into a single-degree-of-freedom system may have to be derived if not already available such as those in Table 6.3 (p. 11-21 on).[81] Appendix G, p.G-8, provides a brief discussion of the use of these factors (simplified to using simply the load-mass factor of Table 6.3), and on p. G-29 there is a comment on the β method and its modification by Beck.[81]

Figure 6-22 shows the basic method in use; although a simple triangular load pulse and elasto-plastic resistance function have been used (to facilitate comparison with a chart solution discussed below), both load and resistance can be complex as mentioned above. Only equations with $\beta = 1/6$ (as recommended by Newmark for the uses made herein) are shown. The time interval h should be short enough to obtain convergence, for each time step, in two to four cycles of calculations; shortening h speeds the convergence (i.e., reduces the number of cycles per time step) but too much so may increase the total amount of calculational effort. Calculations are carried out only until velocity reaches zero, meaning that the maximum deflection has been found and that the ductility ratio μ ($= x_m/x_e$) may be calculated. Other comments are on the figure. For comparison, a time-sharing computer program (thus cheap labor) from which the Newmark β Method could be extracted for separate use furnished the following results, using a time interval h = 0.001 sec.: $x_m = 0.0073$; $\mu = 1.858$. (Compare with 0.0076 and 1.935 from Figure 6-22.)

Figure 6-23 shows the basic method used to find the natural period of (elastic) vibration of the same member as in the preceding figure; the approach is to use an assumed deflection applied to the member,

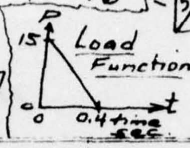
NEWMARK

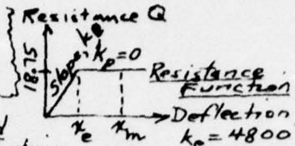
β-method

$$v_1 = v_0 + \frac{h}{2}[a_0 + a_1]$$

$$x_1 = x_0 + h v_0 + \frac{h^2}{6}[2a_0 + a_1]$$

$\beta = 1/6$





$k_e = 4800$ #/in.

$mK_{LM} = 1 \times 0.78$ or 1×0.66 elastic plastic

t	a	v	x	P	Q	$a = \frac{P - Q}{m\,K_{LM}}$
0	—	0	0	15	0	$\frac{15}{.78} = 19.23077$
0.01	14	—	0.000874359	14.625	—	13.36933
"	✓	—	863848	"	—	13.43401
"	✓	0.163324	0.000864926	"	4.15164	13.42738
0.02	0.1	—	0.00294~~575~~ 741	14.25	—	0.1313109 ~~1.313104~~
"	✓	—	294793	"	—	0.1280996
"	✓	—	788	"	—	0.1284289
"	✓	0.231103	0.00294789	"	14.1499	0.1283952
0.03				13.875	$K_{LM} = 0.66$ 18.75	-7.386364
"	✓	0.194813	0.00514009			
0.04				13.5	"	-7.954545
"	✓	0.118108	0.00670943			
0.05				13.125	"	-8.522727
"	✓	0.0357216	0.00748331			
0.06				12.75	"	-9.090909
"	✓	-0.0523466	0.00740492			
Est. $t = 0.05 + \frac{0.0357216}{0.0357216 + 0.0523466} \times 100 = 0.05405613$						
$h = 0.00405613$ 0.05405613				12.972895	"	-8.753189
"	✓	0.0006849	0.00755746			
Est. $h = \frac{0.0357216}{0.0357216 - 0.0006849} \times 0.00405613 = 0.00413542$						
0.05413542				12.969922	"	-8.757694
"	✓	-0.0000093	$0.00755749 = x_m$		$x_e = \frac{18.75}{4800}$	$= 0.00390625$
	$\mu = x_m / x_e = 1.935 \approx 2$					

FIGURE 6-22 NEWMARK β METHOD FOR EQUATIONS OF MOTION

NEWMARK

β-method $\beta = 1/6$

$$v_1 = v_0 + \frac{h}{2}[a_0 + a_1]$$

$$x_1 = x_0 + h v_0 + \frac{h^2}{6}[2a_0 + a_1]$$

Same resistance function -- find natural (elastic) period of vibration T

t	a	v	x	P	Q	$a = \frac{P - Q}{m\, K_{LM}}$
0	—	0	0.001	0	4.8	-6.153846
0.01	✓	—	0.000692308	0	—	-4.260355
"	✓	—	723866	0	—	$-4.4545\overset{5}{7}9$
"	✓	—	720629	0	—	-4.434641
"	✓	-0.0529424	0.000720961	0	3.46061	-4.436684
0.015	-2	—	0.000410943	0	—	-2.528882
"	✓	-0.0703224	0.000408796	0	1.96222	-2.515668
0.02	-1	—	0.000032053	0	—	-0.197252
"	✓	-0.0771548	0.000035315	0	0.169512	-0.217321
0.025	-0.1	—	-0.000352687	0	—	2.110380
"	✓	-0.0724140	-0.000343463	0	-1.648623	2.113614
[h = 0.000466] 0.020466	1	—	-0.000000619	0	—	0.00380723
"	✓	—	655	0	—	0.00402911
"	✓	—	655	0	—	0.00402906
"	✓	-0.0772045	-0.000000655	0	-0.00314267	0.00402906
Natural period of (elastic) vibration				T = 4 × 0.020466 = 0.0819 sec.		

FIGURE 6-23 NEWMARK β METHOD FOR NATURAL PERIOD OF (ELASTIC) VIBRATION

no loading pulse, then calculate the time required for the member to return to zero deflection, which time is of course 1/4 of the natural period; T = 0.082 therefore. In the example, only the first and last cycles are shown for times 0.015 through 0.025. (For this simple problem, the formula $T = 2\pi \sqrt{mK_{LM} / k_e} = 0.080$ would be used, except of course in cases such as this where a numerical method is being demonstrated with a simple problem, the answer to which can be checked, as has just been done, by other means. The point is that the method demonstrated would just as easily handle a curved elastic phase, as with aluminum, or a bilinear "elastic" phase, as with a fixed-fixed single-span beam.)

One blank form for each method, basic and modified, are included herein for the guide user's convenience.

The modified (by J. E. Beck) Newmark β Method, for which a blank form complete with equations is provided herein, was used to solve the problem of Figure 6-22 but with the work done in a computer program; a computer program was also used to solve the same problem with the basic (unmodified) method. With the latter altered from its usual criterion of $\leq \pm 1\%$ to $\leq \pm 0.001\%$ for acceptable agreement between the assumed acceleration (in the last cycle of a time step) and the calculated acceleration, the basic and modified methods gave identical results (six significant figures) for displacement (and within 2 in the sixth figure, for acceleration and velocity) at each time calculated: 0.01, 0.02, 0.03, 0.04, 0.05, 0.06 sec. Clearly, the modified method requires less calculational time, definitely so if a programmable calculator is available (and certainly so on a computer). The modified method is, however, limited to governing differential equations of motion that have <u>linear</u> equations of acceleration, velocity and displacement (see App. G, p. G-29, Ref. 81) - the senior author has never encountered a problem where this limitation would apply (e.g., damping varying with some power, or root, of velocity or displacement; or a curved resistance function that is represented for calculational convenience by a non-linear equation).

NEWMARK

β-method $\qquad \beta = 1/6$

$$v_1 = v_0 + \frac{h}{2}[a_0 + a_1]$$

$$x_1 = x_0 + h v_0 + \frac{h^2}{6}[2a_0 + a_1]$$

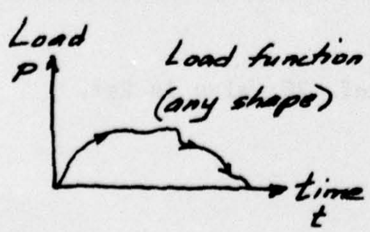
t	a	v	x	P	Q	$a = \frac{P - Q}{m\,K_{LM}} =$
0	–	0	0		0	

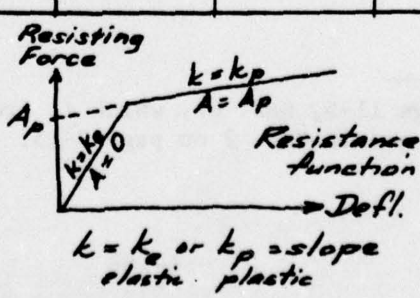
MODIFIED NEWMARK β METHOD (BY J. E. BECK) $\beta = 1/6$

$$x_1 = \frac{x_0 + v_0 h + a_0 h^2/3 + (P - A)h^2/(6\ m\ K_{LM})}{1 + kh^2\ /\ (6\ m\ K_{LM})}$$

$$a_1 = (P - A - kx_1)\ /\ (m\ K_{LM}) \qquad v_1 = v_0 + (a_0 + a_1)h/2$$

t	P	A	k	x	a	v
0		0		0		0





Damping may be included in the method, either as a function of the velocity or displacement or both, thereby adding to the total resistance at each time step; unless used for damping, there is no need to calculate the velocity until the final cycle of each time step in the basic method (as shown by line-outs in Figure 6-22).

In the resistance function, if the slope of the plastic phase is zero, only one cycle of calculations is needed in each time step of the basic method; i.e., because Q or q becomes independent of displacement, each step's acceleration may be directly calculated ($a_1 = (P - Q) / (m\ K_{LM})$), as shown in Figure 6-22.

Comparison of the problem solution (Figures 6-22 and 6-23) with one obtained from charts* may be made as follows: T = 0.082 (Figure 6-22); $t_d = 0.4$ (given); $t_d/T = 4.9$; $p_m/q_y = 15/18.75 = 0.8$ (given); entering the chart with the latter two values gives $\mu = 2$, meaning $x_m = 2\ x_e = 0.0078$, compared with 1.93 and 0.0076 values of Figure 6-22.

* Figure 6.1, page 11-5, Ref. 81, which is from Ref. 20; also in Ref. 16 on page 108 and in Ref. 2 on page 9-15.

D. Probability in Engineering Problems

The purpose of this short paper, prepared as a lecture delivered at the DCPA Staff College in courses in Protective Construction, is to provide insight and a simplified approach to stochastic solution of an engineering problem (in design in this example), instead of the usual deterministic solution; the latter gives a single solution to, say, a beam design problem, whereas the former gives a frequency distribution of many solutions based on a probability approach (simulation or Monte Carlo).

Tools needed for this approach and steps are:

1. Frequency distribution for each significant parameter used in a deterministic solution of the problem. Each parameter must represent a mutually exclusive and equally likely event.[19]

2. Deterministic method for solution of the problem.

3. Source of random numbers (uniformly distributed, <u>not</u> normally distributed).

4. Conversion of each parameter's frequency distribution to a graph of its cumulative probability (%) versus parameter range and values (latter on abscissa scale).

5. Separate random numbers sequence is drawn for each parameter (using 2-digit numbers or the last 2 digits of larger numbers), then applied to the ordinate scale of the appropriate cumulative probability graph to obtain a sequence of values for each parameter.

6. Deterministic solution is performed for each set of parameter values drawn, then a frequency distribution of the results is plotted.

A wood beam design example follows, which better illustrates this stochastic solution technique than would more words. Wood beam design is essentially a 2-parameter method, so was chosen to keep brief the illustrative example.

For many if not most engineering problems, the frequency distribution of parameters may well be limited by lack of data, realistically, to a "flat-topped triangle" (actually a trapezoid).[101] Some help in

providing data, or in pointing to sources of data, is available as are more details on this paper's topic overall field.[102]

Simpler reading, particularly sources that discuss frequency distributions in a more or less easier manner, is available.[19,101,103]

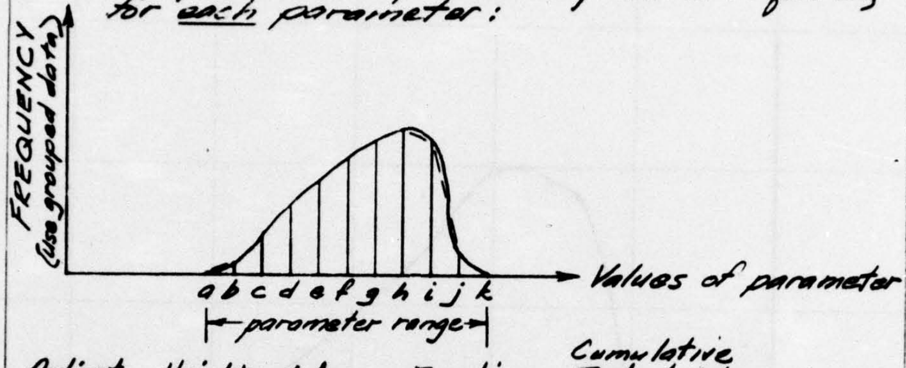
Random number sources are many,[104-106] including commercial time-sharing computer services; a copy of Reference 104 was used in the course lecture. In using 2-digit random numbers (or the last 2 digits of larger numbers) versus cumulative probability graphs running from 0 to 100 on their ordinate scales, the following "rules" (developed <u>after</u> the example calculations, so not used therein) are suggested:

1. If the table (or whatever source) of random numbers is 2-digit, i.e., has numbers only from 00 through 99: add 0.5 to every number drawn, then use the 00.5 through 99.5 numbers to enter the ordinate scale of the cumulative probability plot for which the random number has been drawn.

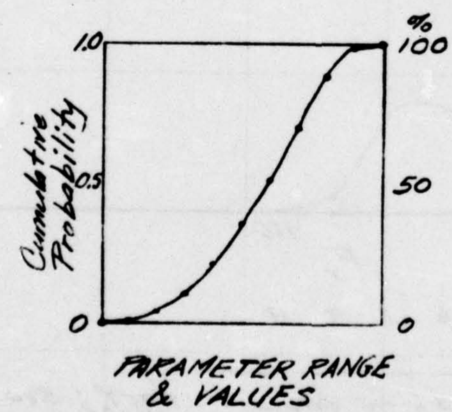
2. If the table or other source of random numbers is 3-digit or larger: read and use only the last two digits, then add 0.5 just as described in the preceding paragraph.

The remaining sheets of this section show the illustrative example, with all calculations; the small difference in effect of 30 to 50 design solutions on the frequency distribution of the resulting wood beam design is shown by the plots.

An example* to show preliminary work required, for each parameter:

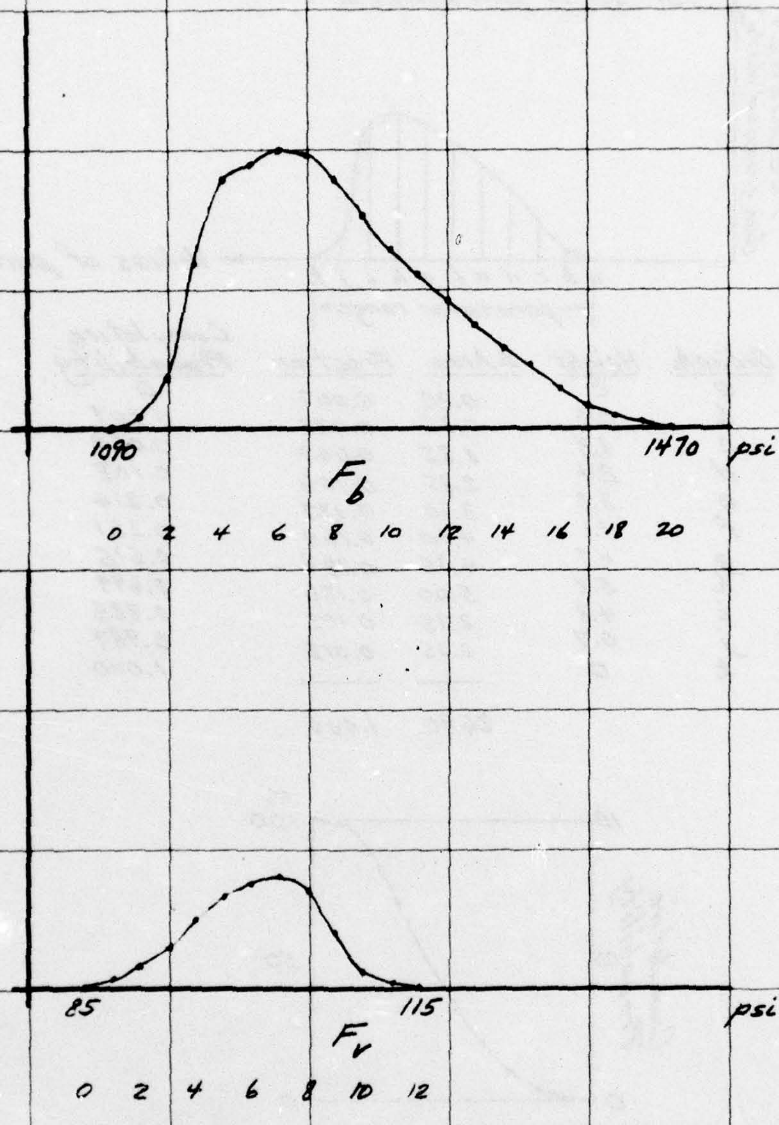


Ordinate	Height	ΔArea	Fraction	Cumulative Probability
a	0	0.20	0.007	0
b	0.4	0.85	0.032	0.007
c	1.3	1.85	0.069	0.039
d	2.4	2.85	0.106	0.108
e	3.3	3.70	0.137	0.214
f	4.1	4.40	0.164	0.351
g	4.7	4.95	0.184	0.515
h	5.2	5.00	0.186	0.699
i	4.8	2.75	0.102	0.885
j	0.7	0.35	0.013	0.987
k	0			1.000
		26.90	1.000	



* Number of significant figures/decimal places used in this example does not imply a degree of accuracy in data or calculations

Frequency distributions for F_b and F_v *

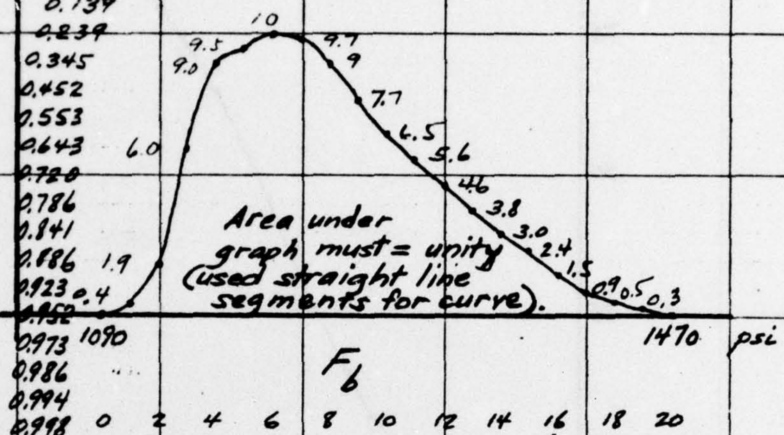


* Strictly assumed; no basis in fact; see U.S. Forest Service "Wood Handbook" for basic data on wood.

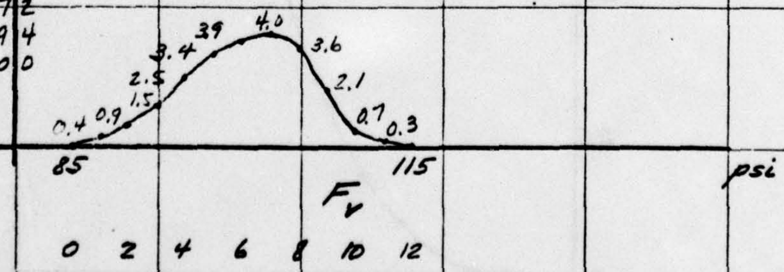
Frequency distributions for F_b and F_v

Calculations

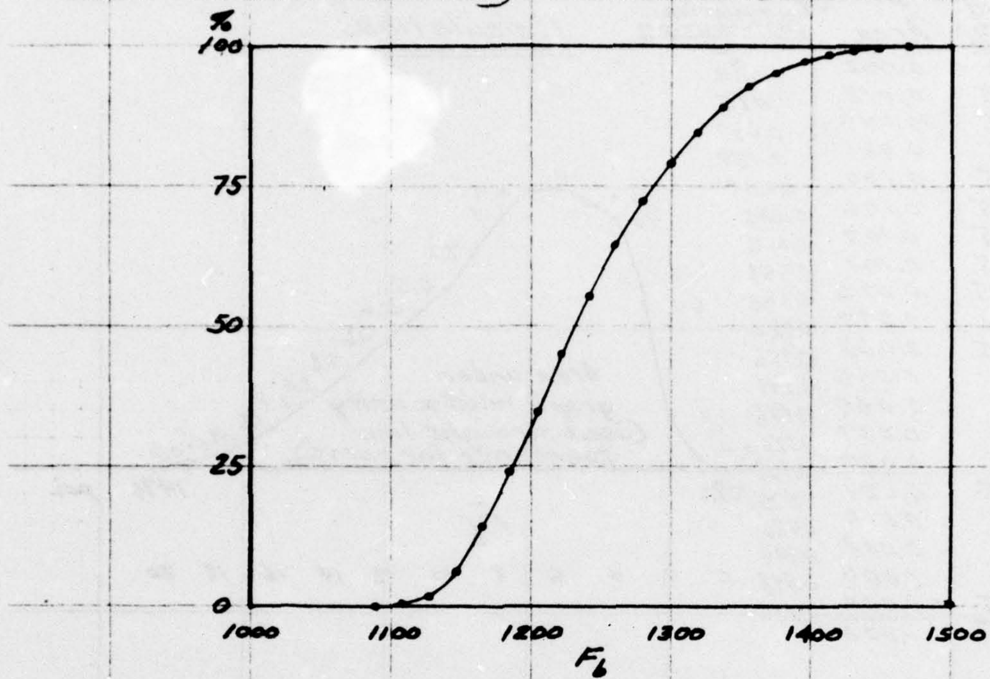
Avg. C.O.	Area	Cumulative Distribution
		0
0.2	0.002	.002
1.15	0.013	.015
3.95	0.043	0.058
7.5	0.081	0.139
9.25	0.100	0.239
9.75	0.106	0.345
9.85	0.107	0.452
9.35	0.101	0.553
8.35	0.090	0.643
7.1	0.077	0.720
6.05	0.066	0.786
5.1	0.055	0.841
4.2	0.045	0.886
3.4	0.037	0.923
2.7	0.029	0.952
1.95	0.021	0.973
1.2	0.013	0.986
0.7	0.008	0.994
0.4	0.004	0.998
0.15	0.002	1.000
92.30	1.000	

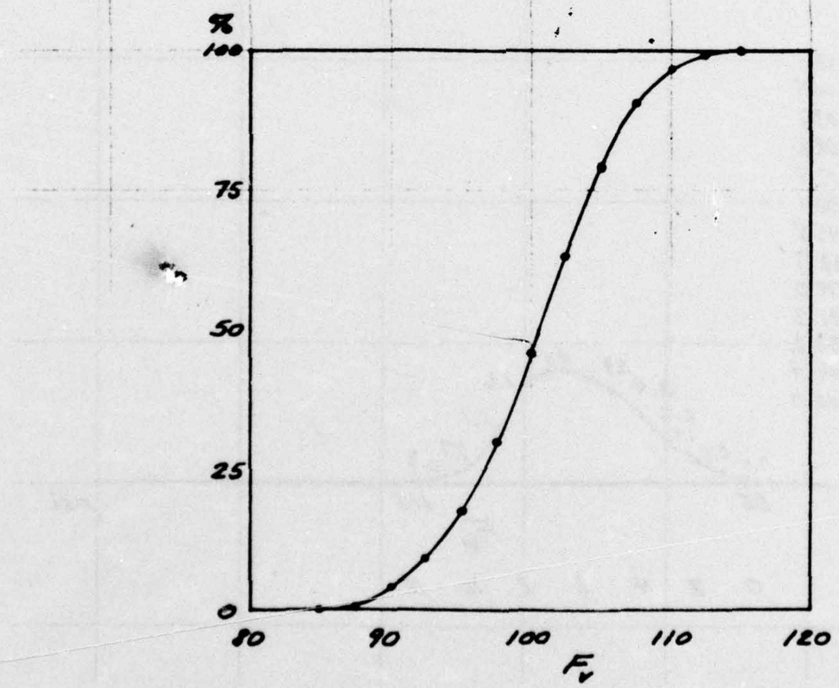


		0
0.2	0.009	.009
0.65	0.028	.037
1.2	0.051	.088
2.0	0.086	.174
2.95	0.127	.301
3.65	0.157	.458
3.95	0.169	.627
3.8	0.163	.790
2.85	0.122	.912
1.4	0.060	.972
0.5	0.022	.994
0.15	0.006	1.000
23.3	1.000	



Cumulative Probability Plots for F_b and F_v





Wood Beam Designs & Random Nos.

Assume wood beam: $d = 3.5$ in. and $L = 35$ in. (simply-supported)

Flexure

$$q_b = 2F_b(d/L)^2/(3c) = 2F_b(3.5/35)^2/\tfrac{3}{8}$$

$$p'_m = \frac{5}{6}q_b = 0.04444\,F_b$$

Horiz. Shear

$$q_v = 8F_v d/[3c'(L-2d)] = 8F_v(3.5)/[3/2\,(35-2\times 3.5)]$$

$$p''_m = \frac{5}{6}q_v = 0.5555\,F_v$$

p_m = smaller of p'_m and p''_m

Random Nos.		F_b	p'_m	F_v	p''_m	p_m
02	32	1090	48.4	97.9	54.4	48.4
99½	58	1451	64.5	101.9	56.6	56.6
11	21	1151	51.2	95.8	53.2	51.2
75	43	1288	57.2	99.6	55.3	55.3
40	37	1215	54.0	99.0	55.0	54.0
82	36	1310	58.2	98.8	54.9	54.9
87	62	1331	59.2	102.4	56.9	56.9
59	92	1250	55.6	108.0	60.0	55.6
98	54	1405	62.4	101.2	56.2	56.2
07	44	1153	51.2	99.7	55.4	51.2
77	14	1293	57.5	94.3	52.4	52.4
50	05	1233	54.8	90.6	50.3	50.3
65	45	1265	56.2	99.7	55.4	55.4
04	08	1109	49.3	87.6	48.7	48.7
75	64	1288	57.2	102.7	57.1	57.1
78	71	1295	57.6	103.6	57.6	57.6
05	75	1147	51.0	104.1	57.8	51.0
20	17	1177	52.3	94.9	52.7	52.3
80	06	1305	58.0	91.3	50.7	50.7
05	20	1147	51.0	95.5	53.1	51.0
49	65	1231	54.7	102.7	57.1	54.7
16	64	1170	52.0	102.7	57.1	52.0
18	23	1176	52.3	96.1	53.4	52.3
61	10	1253	55.7	92.9	51.6	51.6
30	24	1196	53.2	96.4	53.6	53.2
20	96	1177	52.3	109.6	60.9	52.3
59	02	1250	55.6	88.9	49.4	49.4
92	66	1355	60.2	102.7	57.1	57.1
99½	00	1451	64.5	85.0	47.2	47.2
30	20	1196	53.2	95.5	53.1	53.1
						53.0 (mean)

Wood Beam Designs & Random Nos. (concluded)

Effect of running additional solutions:

Random Nos.		F_b	p_m'	F_v	p_m''	p_m
70	57	1272	56.5	101.8	56.6	56.5
71	44	1276	56.7	99.7	55.4	55.4
94	93	1367	60.7	108.5	60.3	60.3
09	79	1155	51.3	104.8	58.2	51.3
65	62	1261	56.0	102.1	56.7	56.0
38	67	1212	53.9	103.0	57.2	53.9
44	52	1221	54.3	100.9	56.1	54.3
72	85	1280	56.9	106.0	58.9	56.9
78	03	1295	57.6	89.8	49.9	49.9
01	64	1120	49.8	102.6	57.0	49.8
						53.4 (mean of 40)
69	35	1272	56.5	98.5	54.7	54.7
99½	12	1432	63.6	93.4	51.9	51.9
35	14	1186	52.7	94.2	52.3	52.3
47	06	1227	54.5	91.3	50.7	50.7
95	54	1375	61.1	101.4	56.3	56.3
41	15	1215	54.0	94.3	52.4	52.4
46	29	1225	54.4	97.4	54.1	54.1
91	54	1349	60.0	101.3	56.3	56.3
48	19	1231	54.7	95.3	52.9	52.9
31	66	1196	53.2	102.1	56.7	53.2
						53.4 (mean of 50)

Extreme values and Tally

Extreme range possible: $\rho_m = 47.22$ to 63.88

ρ_m' ($F_b = 1090$ to 1470): 48.44 to 65.33

ρ_m'' ($F_v = 85$ to 115): 47.22 to 63.88

SIMULATION (Monte Carlo)

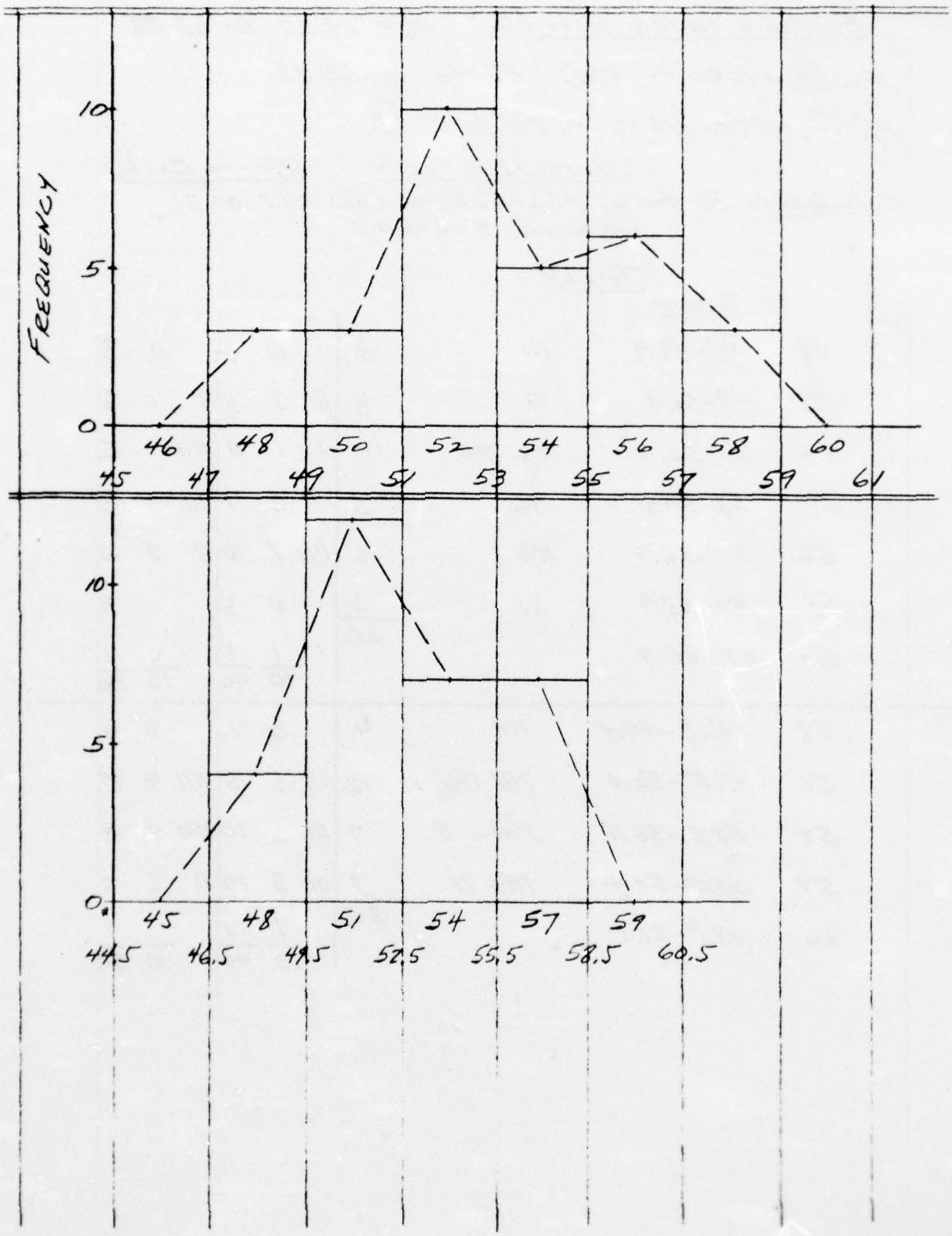
Calculated: 30 trials: 47.2–57.6; 40 trials: 47.2–60.3;
50 trials: 47.2–60.3

TALLY

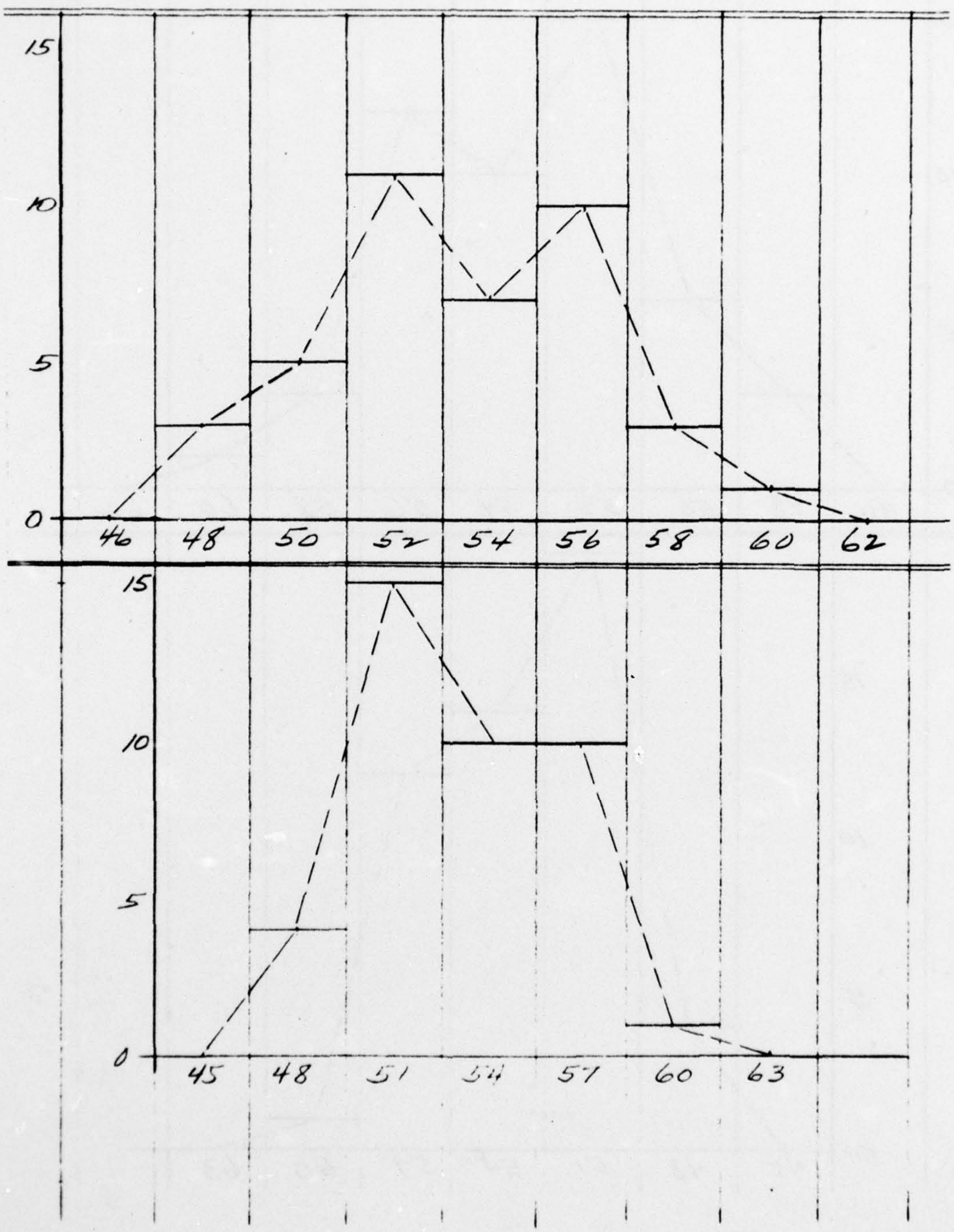
	Interval								
48	47–48.9	|||	3		0	3		0	3
50	49–50.9	|||	3	||	2	5	|	1	6
52	51–52.9	~~||||~~ ~~||||~~	10	|	1	11	||||	4	15
54	53–54.9	~~||||~~	5	||	2	7	|||	3	10
56	55–56.9	~~||||~~ |	6	||||	4	10	||	2	12
58	57–58.9	|||	3		0	3			3
			30						
60	59–60.9			|	1	1			1
					10	40		10	50

48	46.5–49.4	||||	4		0	4		0	4
51	49.5–52.4	~~||||~~ ~~||||~~ ||	12	|||	3	15	||||	4	19
54	52.5–55.4	~~||||~~ ||	7	|||	3	10	||||	4	14
57	55.5–58.4	~~||||~~ ||	7	|||	3	10	||	2	12
			30						
60	58.5–61.5			|	1	1			1
					10	40		10	50

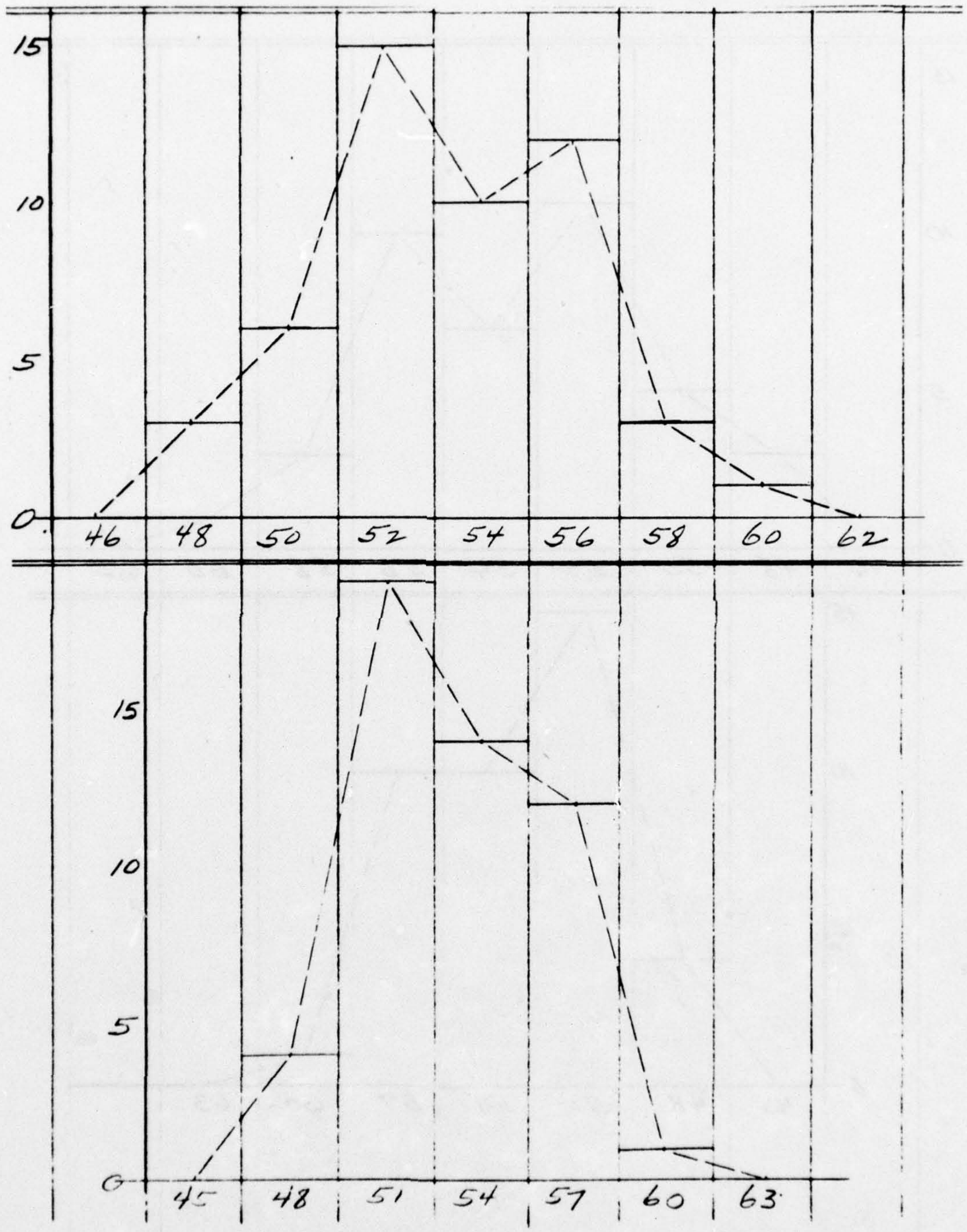
FREQUENCY DISTRIBUTION OF 30 SOLUTIONS



FREQUENCY DISTRIBUTION OF 40 SOLUTIONS



FREQUENCY DISTRIBUTION OF 50 SOLUTIONS



NOTATION

The notation of Tables 6.1 and 6.3 and Figure 6-1 is defined therein and excluded below.

A	area of temperature and shrinkage steel
A, B, C	intermediate equation values used in computing other variables
A_c	area of core of spirally reinforced column measured to the outside diameter of the spiral
A_g	gross area of section
A_s	area of steel in a tension zone
A_s'	area of steel in a compression zone
A_{st}	total area of longitudinal steel in a cross section, e.g., a column
A_v	area of steel in web reinforcement (vertical stirrups) within distance s
a	width of loaded area
a	thickness of wall resting on footing
b	width of beam
b	unit length of wall section under design
$c, c', c'', c_1, c_2, C, C', C''$	dimensionless coefficients
c	ratio of distance between extreme compression fiber of a beam or slab and the neutral axis to depth d (USD)
D	diameter of column
D_e	equivalent design section column diameter used for Table 6.7A
D_s	diameter to the centroid of the vertical bars in a column
d	distance from extreme compression fiber to centroid of tension reinforcement
d'	distance from extreme compression fiber to centroid of compression reinforcement
d''	distance from centroid of tension reinforcement to face of tension reinforcement concrete cover
d_o	distance from extreme compression fiber to the centroid of the tension reinforcement, which produces failure simultaneously in flexure and shear under the same design load

E	modulus of elasticity of section
E_c	concrete modulus of elasticity
E_s	steel modulus of elasticity
e	eccentricity of design load parallel to axis, measured from the plastic centroid, z_o. ($e = M_u/P_u$).
e	base of Napierian or natural logarithms
e'_s	$= \varepsilon'_s$
e_y	$= \varepsilon_y$
F_b	extreme fiber stress in bending
F_{db}	dynamic extreme fiber stress in bending
$F_{c\perp}$	compression stress perpendicular to grain, or bearing stress
$F_{dc\perp}$	dynamic compression stress perpendicular to grain, or bearing stress
F_v	horizontal shear stress (in wood)
F_{dv}	dynamic horizontal shear stress (in wood)
f'_c	static compressive strength of concrete (28-day or later)
f'_{dc}	dynamic compressive strength of concrete
f_{dy}	dynamic (average) yield strength of reinforcing steel
f_y	yield strength of reinforcing steel, specification minimum
f_d	average of dynamic stress factors for steel and concrete = $(f_{dy}/f_y + f'_{dc}/f'_c)/2$
h	same as D, diameter of column
h_e	effective thickness of a column for slenderness
I	cracked section moment of inertia
I_b	in 2-way slab design: I about centroidal axis of beam gross section plus flange on each side equal to smaller of 2 widths: 4 times slab thickness. or beam thickness extending below slab
I_g	moment of inertia of gross concrete area
I_s	moment of inertia of steel area
I_s	in 2-way slab design: I about centroidal axis of slab gross section, using all of slab width as if no beam(s) present (thus, slab width equals ℓ_2, or half ℓ_2 if at discontinuous slab edge)

j	ratio of distance between centroid of compression and centroid of tension, to the depth d (WSD)
K	stiffness factor (elastic phase)
K	weighted dynamic load factor
K_e	dynamic load factor (elastic phase)
K_L	dynamic load factor
K_M	dynamic mass factor
K_o	lateral soil pressure coefficient
K_p	stiffness factor (plastic phase)
K_p	dynamic load factor (plastic phase)
K_R	dynamic resistance factor
k	stiffness factor
k, k'	ratio of distance from the extreme compression fiber to the neutral axis, to depth d (WSD)
k_1, k_2	ratios used in R/C ultimate strength design (see Ref. 32, p. 809-8)
k_3	ratio of the distance from the extreme compression fiber to the neutral axis, to depth d (USD) (same as c)
L	clear height of wall
L	length of structure, or long dimension of rectangular footing, etc.
L	outside (or plan view) dimension of square footing
L	span length of member (clear span, unless otherwise indicated)
L	in wall design sections, see special footnote definitions
L'	bearing length at each end of a wood beam
L_v	length of stirrup steel
ℓ	distance that wall footing protrudes from face of wall
ℓ_d	required development length, in.
ℓ_{da}	available development length, in.
ℓ_n	Napierian or natural logarithms
ℓ/r	ratio of length to radius of gyration
ℓ_u	unsupported length of compression member

ℓ_1	span length (c-c of supports) for 2-way slab span under design
ℓ_2	span length (c-c of supports) transverse to ℓ_1
M	bending moment
M_u	ultimate bending moment
m	mass, unit
n	ratio of steel to concrete moduli of elasticity
P	in-plane applied loading
P_{cr}	critical buckling load of section
P_u	ultimate in-plane capacity of the trial wall or column section
p	reinforcing steel ratio, tension steel, positive moment (p_c = at mid-span)
p	= p_g in column design
p	reinforcing steel ratio, tension steel, positive moment
p′	reinforcing steel ratio, compression steel, positive moment
$\bar{p}$	steel ratio that produces a balanced design in footing
p_c	(see first p above)
p_e	reinforcing steel ratio, tension steel, negative moment
p_e'	reinforcing steel ratio, compression steel, negative moment (end tensile steel)
p_g	= A_{st}/A_g (as used in Table 6.7A in column design)
p_g	= $(1 + \gamma)p = (A_s+A_s')/A_g = 2\ A_s/A_g$ in wall design
p_m	peak (unit) value of applied (air blast) loading
p_r	peak reflected (air blast) overpressure
p_s	ratio of volume of spiral reinforcement to total volume of core (out-to-out of spirals) of a reinforced or composite column
p_{so}	peak side-on (air blast) overpressure
p_v	reinforcing steel ratio, web reinforcement (=A_v/sb, for vertical stirrups)
$\bar{p}_v$	minimum recommended reinforcing steel ratio, web reinforcement
q	static unit load, equivalent to dynamic load in assumed structural response

q yield resistance of member, general

q bearing capacity of footings, psi

q_b bending resistance

q_f ultimate flexural resistance of member

q_v ultimate shear resistance of member

r_o $= (n-1)p'/(np)$, used in computing cracked (transformed) section properties

r/q_y ratio of required rebound resistance to direct load resistance

S spacing between main horizontal bars

s spacing of web reinforcement (vertical stirrups)

T natural period of vibration

t thickness

t_d effective duration

t_e equivalent design section wall thickness used for Table 6.6A

t_m time to reach maximum deflection

t_o duration of positive overpressure phase

t_{oo} duration of initially peaked triangular replacement loading pulse (with decay defined by tangent to overpressure-time curve at p_{so})

u bond stress

u_d allowable dynamic bond strength

V total shear at critical section

V vertical shear in a member

W weapon yield

W conversion factor relating resistance of a one-way slab, spanning in shorter direction of a two-way slab, to resistance of the latter, with resistances in terms of uniform loading on both design slabs

w in 2-way slab design: peak load (at mid-span) per unit length of a support beam (short side of slab)

$\bar{w}$ in 2-way slab design: equivalent uniform load per unit length of a support beam (short side of slab)

$\left.\begin{array}{l} x, x' \\ y, y' \\ z, z' \end{array}\right\}$ intermediate equation values (dummy variables)

z_o	plastic centroid (see a General Note, page 6-89)
x_e	deflection of member at effective yield point
x_m	max. deflection of member
α	stirrup inclination angle
α	ratio of short to long spans (c-c of supports), in 2-way slab design
α_1	$= I_b/I_s$ ($= E_{cb}I_b/E_{cs}I_s$ should be used if $E_{cb} \neq E_{cs}$)
β	coefficient in Newmark β Method (Ref. 21)
β_1	factor used in computing the effective compression area in USD
γ	$= D_s/D$ (see Figure 6.7A); wall design definition in Figure 6.6A
δ	moment multiplier as used in Tables 6.6A and 6.7A
δ	amplification factor associated with P - Δ effect (i.e. in-plane load)
ϵ_s	strain in tension reinforcing steel
ϵ_s'	strain in compression reinforcing steel
ϵ_c	concrete yield strain
ϵ_y	steel yield strain
μ	ductility factor, ratio of maximum to yield deflections
ρ_s	same as p_s

Table 8.0A (Addendum)

ENGINEERING NEWS-RECORD COST INDEXES USED*

Month and Year	EN-R Issue Date	EN-R Issue Page	20-Cities Average† Building Cost Index	20-Cities Average† Constrn Cost Index	San Francisco Building Cost Index	San Francisco Constrn Cost Index
12/67	12/21/67	88	690	1103	764	1318
1/68	3/21/68	85	692	1107	765‡	1317‡
3/68	3/21/68	77	698	1117	768	1316
6/68	6/20/68	118	718	1154	781	1329
6/70	9/17/70	87	830	1369	857	1515
6/71	6/17/71	82	944	1575	1003	1709
6/73	6/21/73	101	1138	1896	NA	NA
3/76	3/18/76	63/67	1378	2322	1514	2813

* In Tables 8.0A through E, to convert from estimates based on 6/68 and 6/70 San Francisco costs to 1/68, 6/71 (report) and 6/73 (report) "20-cities average" estimates.[81]

† All Indexes above are 1913 = 100 base. To convert "20-cities average" Indexes to 1967 = 100 base, divide 1913 = 100 base values by following factors: BCI, 6.7154; CCI, 10.704; MCC, 2.9433.

‡ Obtained by interpolation between 12/67 and 3/68 values.

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98. Handbook of Steel Drainage & Highway Construction Products, 2nd ed., American Iron and Steel Institute, 150 East 42nd Street, New York, N.Y. 10017, 1971.

99. Ferguson, P. M., Reinforced Concrete Fundamentals, 3rd ed. (Wiley), 1973. See Reference 65.

100. Newmark, N. M., "Numerical Procedure for Computing Deflections, Moments, and Buckling Loads," Proceedings of the American Society of Civil Engineers, Vol. 68, 1942, pp. 691-718; also published in A.S.C.E. Transactions, Vol. 108, 1943, pp. 1161-88, plus an extensive Discussion, pp. 1189-1234. See also Reference 73 herein, which is based on Newmark's work, but has expansions by its author. Reference 33 is also excellent on numerical methods.

101. Heggie, I. G., Transport Engineering Economics, Chapter 9: "Methods of Dealing With Uncertainty," 1972 (McGraw-Hill); pp. 225-46 and 250.

102. Benjamin, J. R., and C. A. Cornell, Probability, Statistics and Decisions for Civil Engineers, 1970 (McGraw-Hill). Solutions Manual sold separately.

REFERENCES

103. Arkin, H., and R. R. Colton, Statistical Methods, College Outline Series, 4th ed., revised, 1956 (Barnes & Noble, paper); pp. 1-4, especially.

104. Wilson, E. B., Jr., An Introduction to Scientific Research, 1952 (McGraw-Hill, paper); pp. 286-7.

105. Various electronic (pocket) calculators have random number generators, either built-in or by program provided: HP-25, HP-65, SR-51, SR-52, etc.

106. Handbook of Mathematical Functions, Applied Mathematics Series 55, Nat'l Bur. of Stds., 1964 (Supt. of Documents, Wash. D.C. 20402); pp. 949-53 (5-digit Table, pp. 991-5).

Appendix B

CONTINUITY/CORRECTION SHEETS FOR INCORPORATING APPENDIX A

into Reference 81

(or its predecessors, References 50, 61, 62 and 80)

Cost Estimates

The importance of sound cost estimates for the case studies herein[61] is twofold:

- As a check of the success of each case study, measured against the stated Scope of the guide, a specified level of protection for not more than $6/sf* of shelter space. This criterion was found to be achievable at the conclusion of the third case study.

- As a means of convincing architect/engineer users of the guide that personnel shelter capable of considerably reducing the lethal area around a nuclear detonation is possible through full slanting. This criterion is best served by the description that follows of the cost estimating method used.

As described more fully later in this guide,† each case study building was selected based on its potential for full slanting, original and slanted basement floor plans were prepared, and the latter plan was keyed to illustrate a list of planned modifications. The modifications were carried through design only to an extent reasonably sufficient for cost estimating, perhaps analogous to cost estimating from schematics or preliminary design drawings. Cost estimates were made only for those building components to be modified, in which case separate estimates were prepared for the original and slanted versions, the sought for dollar value being the estimated cost difference, whether an increase or decrease, for each modification. The estimated cost difference is shown for each modification item in the case studies that follow; estimated cost differences of less than about $100 were omitted.† (Study time limitations precluded work to optimize slanting estimated costs.)

Since a construction cost estimate strongly reflects the experience and judgment of the estimator, a well-qualified construction cost consultant made the estimates included in this report.† He used a method generally employed by construction contractors and referred to as the "Quantity and Cost, or Materials and Labor, Method" in an OCD report.[24] The estimates reflect construction costs in the San Francisco Bay Region,‡ during June 1968 for the first three case studies. They include all material and labor costs, labor burden, and contractor's profit. Excluded are such costs as those for planning, design, financing, operating

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* As of January 1968

† In Ch. 8, Ref. 61

‡ But costs <u>are</u> corrected to EN-R's 20-cities average in Table 8-0A, Summary of Slanting Cost Estimates (page 8-69).[61]

and maintenance, etc. The cost estimating approach generally followed that described in another OCD report, which may be consulted for any further details required.[25]

An interesting item came to the author during the preparation of this guide in connection with advertising for construction contract bids for buildings and for alternates with (fallout) slanting incorporated. Invariably the alternates came in at higher bids. An experiment was tried in which a slanted building was used for the basic bid, with the unslanted version to be covered by an alternate - the alternate again came in as the higher bid.*

A later article, prepared by a colleague† about October 1975, discusses full slanting cost estimating in more detail; a copy of the article follows.

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* Attributed to a private discussion with James E. Roembke, then Deputy Assistant Director of Civil Defense (Technical Services), OCD (now DCPA).

† Gilman G. Hoskins, Sr. Architect.

Ventilation and Air Conditioning

As stated in Chapter 1,(50) possession of appropriate professional capabilities has been assumed for each of the design professionals involved in full slanting of a building. For the mechanical engineer or the architect who is to handle the ventilation, including air conditioning if any, adequate preparation should probably include completion of the OCD/DCPA-sponsored course in Environmental Engineering (footnote, p. 1-1), or the equivalent in private study.[26] The general guide in the field includes some discussion of shelter ventilation.[27]

Shelter space allowances (Chapter 1), and thus the metabolic heat from shelterees, are such that system capacities and configurations are largely determined by requirements for cooling rather than heating. Heating problems can often be minimized by partial recirculation of relatively warm air from the shelter.

When outside temperatures are less than 50 F (10 C*), which is the prescribed minimum temperature for shelters, the local environment near openings through which air enters an occupied space may be too cold, unless the fresh air is either heated or mixed with relatively warm air from the space. As outside temperatures fall, the temperature of mixed air supplied to occupied spaces can be maintained at 50 F by varying the relative quantities of fresh and recirculated air. The mixing process is shown by the example on Figure 6-2A:

---

* C = (F - 32) 5/9.

source is a major consideration and a major cost item, if an auxiliary power supply is to be provided.)

Human Tolerances

See note in third item of the Bibliography, and the footnote on page 8-94 of Reference 61. (Project study effort was not available for further work on this topic.)

Typical Designs

The purpose of this section is to provide the manual user - architect or engineer - with several building elements predesigned so that full slanting may be applied, or at least fully considered, with a less than usual design effort.

Typical designs of reinforced concrete elements must recognize steel specifications in current use but not clearly included in Table 6.4 and its sources. These steels are those covered by ASTM Specification Numbers A615 (Billet Steel), A616 (Rail Steel), and A617 (Axle Steel).[30] Use of the latter two steels or A615 Grade 75 is not recommended for protective structures because of possible poor ductility characteristics; if used, they should be handled as indicated in Table 6.4 under "Hard grade or rail steel." A615 Grade 40 has the same specified minimum tensile yield strength (40 ksi) as contemplated by the Table 6.4 "Intermediate grade" entry; A615 Grade 60 has somewhat less ductility, so a ratio of dynamic design tensile yield strength to specified minimum (static) tensile yield strength of 1.2 is recommended.[31]

Values recommended for protective design, and used for the typical designs herein, are therefore as follows.

	Tensile Yield Strength	
	Minimum Static	Dynamic Design
Billet steel, ASTM A615 Grade 40	40 ksi	52 ksi
Billet steel, ASTM A615 Grade 60	60	72

Hook extensions and laps (latter not recommended in blast shelters) in rebars in protection design are recommended to have a 50% increase over the ACI Code[4,60] requirements in terms of bar diameters. Similarly, any planned welding of rebars must be carefully specified[40]* and be of the highest quality, ensured by excellent construction supervision and inspection methods. Later sections in this chapter, Rebar Design and Details, continue the discussion of rebar use, as does an added subsection just below on Rebar Laps and Splices.

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* Use of latest Code edition and close inspection of all welding are strongly recommended for all shelter construction. Preferably, all rebars in blast shelters would be continuous between excellent anchorages; if welding is unavoidable, all rebars thus connected should be sized so as to develop the full strength of each one.

It is especially important in the construction of protective shelter, where large plastic deflections are contemplated in design, that the highest order of construction inspection be applied, to ensure full and absolute adherence to the design drawings/specifications; extremely careful location of all rebars is vital (improper installation, or non-installation, of even one stirrup, for example, has caused failure of a structure in scale model tests).[31]

A. One-Way Slabs - Simply Supported

This section includes simply supported,* one-way slab, typical designs (Figure 6-3A) and rough estimates of related steel and concrete quantities required (Figure 6-3B). The final design procedure and the rebar estimating approach are described in the two subsections that follow. A preliminary design procedure for such slabs, as well as a modified preliminary design procedure and a discussion of the work leading from one to the other, is described in Appendix G, Section I.[50]

Figure 6-3A is solely for designs where $p = 0.02$; it is entered with the desired clear span and values may then be read for: depth d for any combinations of $f_{dy} = 52$ and 72 ksi, and $f'_c = 3$, 4, and 5 ksi; stirrup steel ratio p_v for the same combinations; and rebound steel ratio p' for the same two f_{dy} values (p' is nearly independent of f'_c). Tics on the d versus L curves show peak slab deflection (in.) for $f'_c = 3$ and 5 ksi. All other design parameters and the design procedure followed are discussed in the following section.†

Figure 6-3B provides approximate slab thickness and total weight of reinforcing steel required per foot of slab width, following the same parameters and methods used in preparing Figure 6-3A.‡

Because the prevailing protective structural design methods [2,15,16,22] all use ductility as their yardstick and maximum deflections several times larger than yield deflection are contemplated in such design, some conservatism in dealing with shear and diagonal tension is indicated. In other words, if design is based on highly ductile structural behavior, the designer must take steps reasonably to ensure against shear-type failures, which are likely to be sudden and catastrophic (entire overhead slab coming straight down, versus a ductile failure where one can hope for some survivors under lean-tos or teepees formed by leaning portions of the failed slab). With this background, vertical stirrups are recommended under the following minimums, even when none may be "required" by the design procedure: (1) first stirrup located at d/4 or less from face of support, (2) maximum stirrup spacing throughout at 0.5 d,§ and (3) stirrups to tie all the top and bottom longitudinal steel together (as discussed in later sections, Rebar Design and Details).

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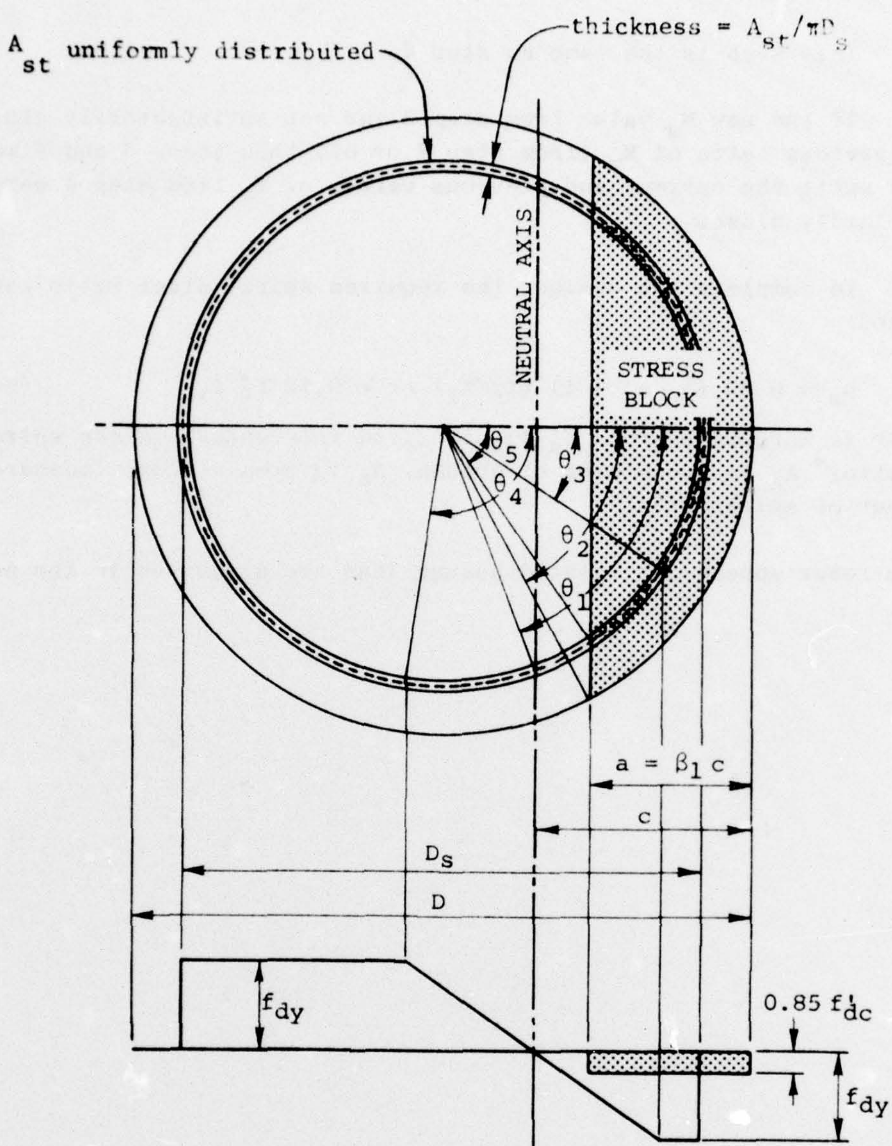
* The section is inapplicable if (moment) continuity with walls applies.

† To illustrate use of Figure 6-3A: assume f_{dy}=52, f'_c=3 and L=300 in.; enter on abscissa scale at L=300 in. and proceed vertically; read maximum deflection about 15.5 in. on curve and d=13.8 in. on right scale; read p_v=0.0110 on left scale; read p'=0.0052 also on left.

‡ To illustrate use of Figure 6-3B: assume f_{dy}=52, f'_c=3 and L=300 in.; enter on abscissa scale at L=300 in. and proceed vertically; read total weight of steel about 570 pounds and approximate concrete thickness about 15.6 in.

§ And no smaller than #3 bars, per section A.5.8, Ref. 60.



SOURCE: Adapted from Ref. 69

FIG. 6-9 STRESS DISTRIBUTION IN CIRCULAR COLUMNS

6. This step is the same as step 4.

7. If the new M_u value from step 6 was not satisfactorily close to the previous calue of M_u (from step 4 or 6), then steps 5 and 6 were repeated until the current and previous values of M_u from step 6 were satisfactorily close.

8. To complete the design, the required spiral steel ratio was calculated:

$$p_s = 0.45\ (A_g/A_c - 1)\ (f_c'/f_y) \text{ or } = 0.12\ f_c'/f_y \qquad (6\text{-}35)$$

whichever is larger, where: p_s (ρ_s in cited references) is the spiral steel ratio;* A_g is gross area of column; A_c is area of core (measured out-to-out of spiral steel).

The rebar scheme and related assumptions are discussed in the next section.

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* For p_s definition: see ρ_s on page 30, Ref. 60. For help on design of spirals: see page 5-17, Ref. 69 or page 34, Ref. 65; and page C-9 is a useful table in Ref. 71 (included later herein as Table 6.8). Source of p_s equations is Ref. 60 (sections 10.9.2 and A.6.4.2).

Rebar Design and Details. The general scheme contemplated for steel detailing is shown in Figure 6-10. In column detailing, required ductility must be maintained to compensate for spalling and is derived from spiral steel serving as web reinforcement (as do stirrups in slabs and beams). Because of this, a design procedure is recommended that complies with the requirements of Ref. 60, Appendix A (Special Provisions for Seismic Design), Section 6 (Special Ductile Frame Columns Subjected to Axial Loads and Bending), some aspects of which are: Spiral reinforcing steel should extend from the floor level in each story up to the lowest horizontal reinforcement of the next floor level:* two extra turns of spiral bar or wire at each end of the spiral unit are required for anchorage; spiral spacers must be provided as shown in Table 6.8; and, minimum suggested bar size for spiral steel is number 3.

Table 6.9 gives percentages and weights of standard steel reinforcing spirals. When computing the length of the column's longitudinal rebars, for estimating required steel quantities, the length used should be from floor level of the story considered up to the floor level of the story above, because only welded, not lapped, bars are contemplated.

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* See also NOTE, Fig. 6-10.

68. Derivation of Equations, Ultimate Strength Design Handbook Volume 2, Columns, Supplement to SP-17A, American Concrete Institute, Detroit, Michigan (originally published as SP-7 until superseded by Ref. 70, but latter omits material now in this reference; available in xerographic reproduction from ACI).

69. Columns by Ultimate Strength Design Including Square Footings, Concrete Reinforcing Steel Institute, Chicago, Illinois, 1967.

70. Ultimate Strength Design Handbook, VOLUME 2, COLUMNS, Special Publication No. 17A, American Concrete Institute, Detroit, Michigan, 1970.

71. Rippstein, E. E., Reinforcing Bar Detailing, Concrete Reinforcing Steel Institute, Chicago, Illinois, 1970.

72. Manual of Standard Practice for Detailing Reinforced Concrete Structures (ACI 315-74), 6th ed., American Concrete Institute, Detroit, Michigan, 1974.

73. Godden, W. G., Numerical Analysis of Beam and Column Structures, 1965 (Prentice-Hall, Inc.); Chapters 1 and 3 (Reference 1.4 may be useful for source background).

74. Wiehle, C. K., Summary of the Dynamic Analysis of the Exterior Walls and Floor Systems of 50 NFSS Buildings, Stanford Research Institute Technical Report for U. S. Defense Civil Preparedness Agency, Washington, D. C., June 1974 (limited distribution; not in DDC).

75. DCPA Attack Environment Manual, Chapter 4, Research Directorate, Defense Civil Preparedness Agency, Washington, D. C. 20301, June 1972.

76. EMP Protection for Emergency Operating Centers, TR-61-A, May 1971, DCPA.

77. EMP Protective Systems, TR-61-B, November 1971, DCPA.

78. EMP and Electric Power Systems, TR-61-D, July 1973, DCPA.

79. Cohen, E., and E. B. Laing, "Perimeter Acquisition Radar Building at Safeguard Complex," ACI Journal, Spetember 1974, American Concrete Institute, Detroit, Michigan 48219.

80. Murphy, H. L., and J. E. Beck, Slanting for Combined Nuclear Weapons Effects: BLAST-RESISTANT DESIGN/ANALYSIS WITH EXAMPLES, Stanford Research Institute Technical Report, for Defense Civil Preparedness Agency, December 1974. (AD-A016 631)*

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* Report contents are included in this Consolidated Printing of four reports.

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Merritt, J. L., and N. M. Newmark, Design of Underground Structures to Resist Nuclear Blast, U. of Ill., Civil Engineering Studies, Structural Research Series No. 149, April 1958. Suggested by Professor W. J. Hall (University of Illinois) as being basic to AFDM (Ref. 2).

Personnel Shelters & Protective Construction, NAVDOCKS P-81, Navy Bureau of Yards & Docks (now Naval Facilities Engineering Command), Washington, D.C., Sept. 1961; plus Change 1 (2/7/62) and Change 2 (7/9/62). Consider for effects data, structural and other analyses, etc., and review for slanting ideas.

Project Harbor report, about 1964 (not Little Harbor, a more recent report). Suggested by Professor Hall, particularly in connection with human tolerances.

Modification of Existing Buildings as Community Shelters, DRAFT for OCD Prof. Guide Series, Ammann & Whitney, Jan. 1965.

Suggested Building Code Provisions for Fallout Shelters, report prepared by Graves-Hill & Assoc., Architects, Lexington, Ky., for OCD, TR-36, May 1966. Contains review of various building codes.

Denton, D. R., A Dynamic Ultimate Strength Study of Simply Supported Two-way Reinforced Concrete Slabs, USA-WES Tech. Rpt. 1-789 prepared as final report for OCD, July 1967.

Janney, J. R., "Full-Scale Structural Testing and the New York World's Fair," Civil Engineering, ASCE, December 1968.

Raths, C. E., N. L. Scott, and J. R. Janney, Full-Scale Testing of New York World's Fair Structures, Volume I, The Bourbon Street Structure, Building Research Advisory Board, National Academy of Sciences, Washington, D.C., 1969.

The three bibliographic items above will be considered for floor slab analyses of structural resistance.

Heugel, W. F., and D. I. Feinstein, Shelter Evaluation Program, IITRI Technical Center Final Report, project M6088 to OCD (task 1614A), February 1967.

Longinow, A., Civil Defense Shelter Options for Fallout and Blast Protection (Dual-Purpose), IITRI Final Report for OCD, May 1967.

Longinow, A., et al., Civil Defense Shelter Options, IIT Research Institute Interim Report for OCD, November 1970.

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Wiehle, C. K., and J. L. Bockholt, Existing Structures Evaluation, Part I: WALLS, Stanford Research Institute Technical Report prepared for OCD, November 1968 (AD-687 293).

Iverson, J. H., Existing Structures Evaluation, Part II; Window Glass and Applications, Stanford Research Institute Final Report prepared for OCD, December 1968 (AD-687 294).

Jensen, G. F., Existing Structures Evaluation, Part III: Structural Steel Connections, Stanford Research Institute Report prepared for OCD, December 1969 (AD-701 088).

Wiehle, C. K., and J. L. Bockholt, Existing Structures Evaluation, Part IV: Two-Way Action Walls, Stanford Research Institute Technical Report prepared for OCD, September 1970.

Allen, F. C., "Environmental Control Systems," Chapter VII, Parametric Study of Shelter System Costs by T. J. Logothetti et al, Stanford Research Institute report for U.S. Office of Civil Defense, Washington, D.C., January 1969.

The following ten reports were reviewed, seeking actual or potential changes in guidance affecting the design of footings to resist dynamic loads. Review results indicated no change, only support, of the guidance already provided by Reference 2 recommendations.

Carroll, W. F., Dynamic Bearing Capacity of Soils, Report 5; Vertical Displacements of Spread Footings on Clay: Static and Impulsive Loadings, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, Technical Report No. 3-599, Sept. 1963 (AD-450 619).

Jackson, J. G. Jr., and P. F. Hadala, Dynamic Bearing Capacity of Soils, Report 3; The Application of Similitude to Small-Scale Footing Tests, USAEWES Tech. Report No. 3-599, Dec. 1964 (AD-454 374).

N. M. Newmark and Associates, Design of Model Test Program for a Buried Field Shelter, USAEWES Contract Report No. 1-110, May 1965 (AD-465 567).

Hadala, P. F., Dynamic Bearing Capacity of Soils, Report 4; Investigation of a Dimensionless Load-Displacement Relation for Footings on Clay, USAEWES Tech. Report No. 3-599, June 1965 (AD-467 081).

Lysmer, J., Vertical Motion of Rigid Footings, USAEWES Contract Report No. 3-115, June 1965 (AD-469 600).

Poplin, J. K., Dynamic Bearing Capacity of Soils, Report 2; Dynamically Loaded Small-Scale Footing Tests on Dry, Dense Sand, USAEWES Tech. Report No. 3-599, Sept. 1965 (AD-623 516).

Drnevich, V. P., J. R. Hall, Jr., and F. E. Richart, Jr., Transient Loading Tests on a Rigid Circular Footing, USAEWES Contract Report No. 4-146, Feb. 1966 (AD-631 369).

Meyer, G. D. and W. J. Flathau, Static and Dynamic Laboratory Tests of Unreinforced Concrete Fixed-End Arches Buried in Dry Sand, USAEWES Tech. Report No. 1-759, Feb. 1967 (AD-650 851).

Kennedy, T. E. and J. T. Ballard, Dynamic Test of A Model Flexible-Arch-Type Protective Shelter, Report 1; Pilot Test, USAEWES Tech. Report No. 1-768, Apr. 1967 (AD-651 349).

Hadala, P. F. and J. G. Jackson, Jr., A Model Study of the Small Boy Footing Behavior, USAEWES Tech. Report No. 3-793, Aug. 1967 (AD-659 254).

Appendix C

SELECTED CORRESPONDENCE CONCERNING CONSULTATION VISITS TO PERSONNEL OF REGIONS 4 and 7

DEFENSE CIVIL PREPAREDNESS AGENCY
REGION SEVEN
POST OFFICE BOX 7287
SANTA ROSA, CALIFORNIA 95401

MAR 8 1976

Captain H. L. Murphy
Manager, Facilities and Housing Research Group
Stanford Research Institute
Menlo Park, California 94025

Dear Captain Murphy:

I wish to thank you for your able assistance to Mr. James Brown of this office in the February 19, 1976, meeting with Mr. Don Kasamoto, architect, and Mr. Victor Bar-Din, structural engineer, regarding the blast hardening of the new Alameda Police Administration Building.

We were informed subsequent to the meeting that the architect discussed blast hardening with Lt. Charles Wood of the Alameda Police Department and furnished him an estimate for an additional $100,000 for blast hardening the basement to 15 psi. Lt. Wood was reluctant to pursue the extra cost with the City Council for fear of getting the whole project cancelled.

In response to your request for copies of our latest guidance on funding for blast hardening, we are enclosing a copy of the title page and paragraph 3.31(2), CPG 1-3.

Thanks again for all your assistance.

Sincerely,

Frances K. Dias
Regional Director

Enclosures 2

BICENTENNIAL AMERICAN REVOLUTION 1776-1976

4620-7

SRI

MEMO

TO: G. N. Sisson, DCPA
M. A. Pachuta, DCPA

DATE: 3/4/76

FROM: H. L. Murphy, SRI

LOCATION:

SUBJECT: EOC under design for Alameda, Calif; rejection of adding blast-full slanting to

CC:

Ref: My memo of 2/27/76, same subject.

1. Fonecon of a few minutes ago with Jim Brown, DCPA Region 7 RESG, advised that the city people, concerned with the new building that is to include an EOC for Alameda, are unwilling to go to the city fathers for any more money at all, for fear of getting the entire project cancelled. In short, the already planned fallout slab over the basement is all they go for. (I doubt that the matter got to even the City Manager.)

2. Two lessons appear to be clear from our experience with this EOC-under-design:

a. We must get involved much earlier in the planning/design phases;

b. We must continue to work on our design programs, getting more of them into computer programs (including at least preliminary estimates of quantities), so that we can, in effect, perform the slanting alternative designs for the A&E (subject to his "check," of course, if he knows how and if the final decision is to use them).

3. The lesson of paragraph 2a is being applied to State EOC expansion at Austin, Texas - see another memo on that subject, dated today.

Best regards,
H. L. Murphy

SRI 2003 R2

DEFENSE CIVIL PREPAREDNESS AGENCY
REGION FOUR
FEDERAL CENTER
BATTLE CREEK, MICHIGAN 49016

Mr. H. L. Murphy
Stanford Research Institute
Menlo Park, California 94025

Dear Mr. Murphy:

The June 18, 1976, meeting with the architects, structural and mechanical consultants and local officials has resulted in a positive attitude for consideration of blast-resistant design in the proposed new Stark County, Ohio, Engineer Office Building and EOC.

When we requested your assistance we were aware that design funding for an EOC had not been approved by the County. However, we all know that if a new or different design concept is desired in a particular structure, it is best to plant the seed (which has been accomplished) before schematics are begun.

We thank you for taking time out of your busy schedule to accommodate our request and recommend that this advisory type of service continue to be made available until our Resident Engineering Support Group personnel have had a chance to work on two or three projects being designed for blast resistance.

Sincerely,

Bruce Bishop

Bruce Bishop
Regional Director

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

4620-4

STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA 94025
(415) 326-6200

June 28, 1976

Defense Civil Preparedness Agency
Attn: Dr. M. A. Pachuta
Contracting Officer's Technical Representative
Commonwealth Building, Room 1048
1300 Wilson Boulevard
Arlington, Virginia 22209

Reference: Contract No. DCPA 01-76-C-0161
DCPA Work Unit No. 1154H

Gentlemen:

In response to a request of a DCPA Region 4 RESG engineer, Mr. Bruce R. Newhard, I accompanied him and Mr. D. Bement of the Region 4 staff to a meeting on June 18, 1976 with the Stark County (Ohio) Engineer/County Disaster Services Agency Director, his staff, and his prospective architects and engineers for a belowground, 10,000 sf expansion of county building spaces, the intention being to discuss inclusion of some level of nuclear attack and natural disaster (tornado) protection for this space, and to make it serve both normal and EOC uses.

The attached copy of my letter to the County Engineer reviews the meeting, my extensive briefing, and the publications (both final and draft) left for further consideration. The reception to consideration of arch and conduit structures as an alternative to the usual rectilinear structures was definitely a positive one; however, my briefing, the questions and the general discussion were aimed at providing full information, within time constraints, on all salient aspects of both structural approaches, as ll as many ventilation and emergency exit matters.

Mr. Newhard and I made a near-airport Cleveland motel our rendezvous point on June 17, for my travel by air from San Francisco and his by own car from Battle Creek; timing was such that we had dinner together, which was followed by an extensive discussion meeting. The latter quickly disposed of necessary preliminary details concerning the Canton (Stark County seat) meeting set for 0830 the next morning, then turned to discussion of Mr. Newhard's concerns about a planned county EOC at Chilton (Calumet County), Wisconsin, where only negligible blast

protection could be considered because of its low risk area. I recommended that he try to use the ventilation ducts/emergency exits described below, thereby gaining highly protected shelter as a by-product. The meeting at Canton began about 0830 and concluded at the end of lunch with Mr. Cammel (1330); discussions with DCPA/RESG personnel continued during a ride in Mr. Newhard's car until we separated at Toledo, Ohio at 1630.

The matter of the Chilton "host area" EOC bears some discussion, because it is probably representative of many similar situations. For example, a county EOC in a low risk county, but one that serves as a "host area" for a nearby higher risk population-industry area(s), can have an extremely important role to play in saving lives. This role cannot be fulfilled if the EOC has so little protection as to be vulnerable to nuclear attack (certainly fallout, if not direct effects, as from a MIRV scatter attack around the population-industry or military target, or from a large yield weapon aimed at a point between two major targets and of sufficient yield to give the damage desired on both), or tornado damage (as in the instant case), or other natural disasters (hurricanes, earthquakes, etc.). Certainly the EOC should be strong enough to survive the weight of debris from the aboveground portion of its parent building; it should have ventilation/emergency exit ducts of sufficient strength and length to allow the EOC occupants to escape, despite debris from, or fire in, the aboveground building.

In the instant case, I suggested ventilation ducts/emergency exits on two opposite sides of the aboveground building, extending 50 or 60 ft away from the building (and any other buildings), which is a suggestion made and used often. In normal use, one duct could be for intake air, the other for exhaust air, and the exhaust air could be sent out through an enlargement in the duct/emergency exit, which enlargement could house the emergency power source for at least minimal ventilation and lighting.[*] Further, such ventilation ducts/emergency exits could be constructed of circular R/C sewer pipe or corrugated-steel conduits, or corrugated-steel junior underpass (formerly "cattle-pass") sections. Each duct could provide protection against all nuclear weapons effects, including fallout and 60 psi or higher blast and related effects protection,[†] as well as all natural disasters except flooding; to achieve such protection, the ducts should connect an opening in the basement wall with a man-hole type of structure, and simple blast closure doors should be used to close off both ends of the duct.[‡] Such a ventilation ducts arrangement should provide sufficient space for emergency use by all of the usual occupants of an EOC, either in small circular conduits (say, 36 in. diam. or more; prone or sitting) or in such as the cattle-pass sections (say, 5'10" x 7'8" high) where there is sufficient room for a double-tier of bunk shelves down one side. In summary, an emergency exit, or combination ventilation duct/emergency

exit, could be justified in many situations - personnel left in "high-risk" areas or moved into "host areas" or in EOCs - and with proper materials selection and design detailing could provide a very high level of protection indeed.

This letter together with its enclosure represents the assistance effort, under referenced contract, provided to DCPA Region 4 professionals (RESG and staff), and to the Stark County (Ohio) Disaster Services Agency Director and his staff/engaged professional engineers and architects. The assistance was given prior approval in a fonecon with the COTR. It is hoped that this report fulfills its intended need; comments are invited and would be appreciated.

Sincerely yours,

H. L. Murphy

H. L. Murphy, P. E.
Project Leader

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* Reference 1; pp. 8-2 thru 8-6, pp. 8-88 thru 8-91, Appendix H, and Appendix H.1 (pp. -11 and -12).

† Reference 2 and its references list.

‡ Reference 1; pp. 6-107 thru 6-118 and p. 8-7.

REFERENCES

1. Murphy, H. L., J. R. Rempel, and J. E. Beck, SLANTING IN NEW BASEMENTS FOR COMBINED NUCLEAR WEAPONS EFFECTS: A Consolidated Printing of Four Technical Reports, Stanford Research Institute Technical Reports, 3 vols., for U.S. Defense Civil Preparedness Agency, October 1975. (AD-A023 237)

2. Murphy, H. L., H. Arch and Conduit Structures - Corrugated-Steel and Reinforced Concrete, DRAFT paper 4620-5 of 5/76 by SRI for DCPA; 20 pp.

Enclosure

cc: Mr. Bruce R. Newhard, RESG, DCPA Reg. 4 (w/encl)
Mr. D. Bement, DCPA Reg. 4 (w/encl)
Mr. G. N. Sisson, Hqtrs, DCPA (w/encl)
Stark County Engineer, Canton, Ohio (w/o encl)

4620-4

STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA 94025
(415) 326-6200

June 28, 1976

County Engineer, Stark County
County Office Building
209 West Tuscarawas Street
Canton, Ohio 44702

Attn: S. A. Cammel, Deputy County Engineer (Administration)

Dear Sir:

On June 18, I accompanied Mr. Bruce R. Newhard of the Defense Civil Preparedness Agency's Region 4 RESG, Battle Creek, to a meeting in your offices, the subject being early planning for an addition to your county office spaces of about 10,000 sf of belowground space for dual use, normal and EOC. The meeting began at 8:30 a.m. and continued until lunch time generally; it extended through lunch but only with your Mr. Cammel, and Messrs. Newhard and D. Bement of DCPA. Our participation was intended to be advisory only, in which connection I gave an extended briefing and left one copy each of the following documents for your staff:

- Murphy, H. L., J. R. Rempel, and J. E. Beck, SLANTING IN NEW BASEMENTS FOR COMBINED NUCLEAR WEAPONS EFFECTS: A Consolidated Printing of Four Technical Reports, Stanford Research Institute Technical Reports, 3 vols., for U.S. Defense Civil Preparedness Agency, October 1975. (AD-A023 237)

- Arch and Conduit Structures - Corrugated-Steel and Reinforced Concrete - consisting of 20 pages, DRAFT copy.

The briefing covered many matters that are included in the above 3-volume publication (available for purchase, if additional copies are needed, from NTIS, Springfield, Virginia 22151, by citing the "AD-" number shown); for example, matters from Chapters 6, 8 and 10, as well as Appendixes E through H, were covered in the briefing to varying degrees.

A second set of copies of the above two publications is enclosed, as well as one set of DRAFT notes on special topics as follows:

- Rebar Laps and Splices - consisting of three pages.
- Numerical Methods for Structural Analysis - consisting of 23 DRAFT pages.
- Alternate Final Design Procedure (for symmetrically reinforced walls) - consisting of 16 pages.
- Table 8.0A (addendum) - Engineering News-Record Cost Indexes Used - consisting of two pages.
- Probability in Engineering Problems - consisting of 15 pages. This set has no suggested pagination - recommend putting it just ahead of page 6-119.

Finally, by copy of this letter, the structural engineer attending the meeting, R. I. Campbell, P. E., is furnished with one copy each of the above DRAFT papers, at his earnest oral request made at the meeting.

All DRAFT papers are paginated for insertion in the 3-vol. publication, except as noted above.

I enjoyed meeting with your personnel and the attending architects, and mechanical, electrical and structural engineers. I found them quick to grasp concepts and information from a field that I believe was largely new to them, as well as open to new approaches to your problem of a considerable addition of county dual use (normal/EOC) office space, in particular the potential use of arch and conduit structures as an alternate to the usual rectilinear structures.

It would be a pleasure to assist you further in any way I can. Arrangements should be made, of course, through the DCPA Region 4 RESG, as before. Best wishes for the success of your expansion plans and for a minimum of problems and obstructions.

Sincerely yours,

H. L. Murphy

H. L. Murphy, P. E.
Manager
Facilities and Housing Research

cc: Mr. G. N. Sisson, Hdqtrs, DCPA
Dr. M. A. Pachuta, " "
Mr. Bruce R. Newhard, RESG, DCPA Region 4
R. I. Campbell, P. E. (Cleveland)

Appendix D

RECENT LETTERS OF SUPPORT FOR CONTINUED AVAILABILITY OF ON-CALL SPECIALIZED TECHNICAL HELP

from

DCPA Regions 3, 5 and 6, and the
Army Office of the
Chief of Engineers

DEFENSE CIVIL PREPAREDNESS AGENCY
REGION THREE
FEDERAL REGIONAL CENTER
THOMASVILLE, GEORGIA 31792

February 22, 1977

Mr. H. L. Murphy
Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, CA 94025

Dear Mr. Murphy:

We have many areas in Region Three that require blast resistance in their vital Emergency Operating Centers.

Changes such as the introduction of blast resistance into the local EOC, are accepted verly slowly by our local governments. In the near future we expect to start building five to fifteen psi overpressure resistance into Emergency Operating Centers.

While we have training in the theory and design of blast resistance structures we cannot provide consultants with the capability to provide immediate working knowledge of specially blast resistant design to the architectural profession because we have not done enough practical design work to maintain proficiency in this highly specialized field. Over the next year or two it will be very important to us to have the services of a consultant with special expertise in blast resistance design. It will expedite our EOC program and be cost effective also when the program is looked at in its entirety. We hope you will continue to make such expertise available while the blast resistant program is undergoing its birth pains.

Sincerely,

Roy O. Wilham

Roy O. Wilham
Chief, Engineering Services

DEFENSE CIVIL PREPAREDNESS AGENCY
REGION FIVE
FEDERAL REGIONAL CENTER
DENTON, TEXAS 76201

MAR 2 1977

Mr. H. L. Murphy
Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, California 94025

Dear Mr. Murphy:

The technical consultation you provided to the State of Texas during 1976, concerning the blast-resistant design of their EOC expansion was greatly appreciated, both by the State and Region Five. The final plans for the Texas State EOC expansion have not been completed; however, preliminary plans have been submitted to the Texas State Department of Public Safety (DPS) Building committee for review and recommendations. The technical advice you provided on multi-plate steel arches, to the State and Region Five during your personal visit, may well lead toward a more economical and superior blast-resistant structure. The specialized technical assistance of the type you provided will be needed more than ever as DCPA moves into the field of Crisis Relocation Planning.

Thank you for your time and personal interest in our Texas project. I expect several other blast-resistant EOC's will be considered for construction in high risk areas in Region Five during the next year or two.

I trust that you found Region Five hospitable enough to assist us once again as the need arises.

Sincerely,

Kyle Thompson

Kyle Thompson
Regional Director

DEFENSE CIVIL PREPAREDNESS AGENCY
REGION SIX
DENVER FEDERAL CENTER, BUILDING 710
DENVER, COLORADO 80225

February 15, 1977

Mr. H. L. Murphy
Stanford Research Institute
Menlo Park, California 94025

Dear Mr. Murphy:

Messrs Charles Powell and David Prothero of our RESG Staff completed your class in Protective Construction, covering the concept of slanting blast protection into new construction involving civil defense facilities.

Mr. Powell has brought to my attention that your services as a consultant are available to each Region, if and when needed, to persuade Architects, Engineers, and Local Officials to blast slant the design of new EOCs in high risk areas.

We in Region Six have not availed ourselves of your services as yet, but hope to do so in the not too distant future. We are working on two or three EOC projects in high risk areas that are about to the stage of development where your personal services would get the job done.

We certainly hope your services will continue. We agree it is impractical and illogical to expect engineers, who must have a general understanding of the total field of engineering, to also be expert in the highly specialized field of blast protective design in structural engineering. First, many qualified structural engineers have not had the advanced degree training coincident with this specialty to become fully expert. Second, the engineers in the Region do not encounter sufficient numbers of projects requiring this level of design to become wholly proficient in the protective design.

I look forward to our working together when time dictates.

Sincerely,

D. G. Harrison
Regional Director

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

REPLY TO
ATTENTION OF:

DAEN-MCP-C

25 February 1977

Mr. H. L. Murphy
Stanford Research Institute
Menlo Park, California 94025

Dear Mr. Murphy:

We appreciate your continued support of the National Shelter Survey and related programs particularly in the field of nuclear blast resistance.

Your training of our selected engineers at the Defense Civil Preparedness Agency Staff College, Battle Creek, Michigan, has been of great value. Most important is the consulting support that you have furnished to our field personnel, in the past, when a specialist in the field of dynamic loadings was required.

We trust that you will endeavor to fit us into your busy schedule, in the future, when we need help.

Sincerely,

F. J. TOMASSONI
Acting Chief, Civil Preparedness Branch
Program, Planning and
Civil Preparedness Division
Directorate of Military Construction

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MAXIMIZING PROTECTION IN NEW EOCs FROM NUCLEAR BLAST AND RELATED EFFECTS: GUIDANCE PROVIDED BY LECTURE AND CONSULTATION (UNCLASSIFIED)

By: H. L. Murphy and J. E. Beck

Stanford Research Institute, Menlo Park, Calif., Sept. 1976, 194 pages
Contract No. DCPA01-76-C-0161, DCPA Work Unit 1154H

The project was devoted to providing consultation and lecture guidance on applications of combined nuclear effects slanting techniques to new basements (all EOCs). The bulk of the report consists of several appendices that publish additional slanting guidance, found needed or useful while providing the consultation and lecture assistance. The new guidance has been so arranged that it may be added to the previously published guidance,[1-5] by using Appendices A and B herein.

Lecture Guidance/Assistance

Two special lecture courses were given for the purpose of familiarizing DCPA Region Staff and RESG engineers - whose normal work is representing the U.S. Government's interests in the contract construction of EOCs under matching funds - with combined nuclear effects slanting (design modifications) of such EOCs, especially for air blast resistance; they were held at the DCPA Staff College, Battle Creek. The Project Leader, H. L. Murphy, was a consultant-lecturer backing up the course director, Thomas P. Carroll. Generally, Mr. Carroll introduced each subject area using the TR-20 Vol. 4 DRAFT as a basic source, and in a lecture following soon thereafter Mr. Murphy discussed the subject in terms of full slanting with reference made to pertinent portions of the 3-volume slanting guidance handout,[5] as well as to special lecture topics.

Complete notes on most of the special lecture topics are in Appendix A.

Consultation Guidance/Assistance

There were many informal discussions, mostly telephonic, with or through students from the above courses, which amounted to consultation on potential applications of full slanting to EOCs. There were a few field cases where a report was made to DCPA; selected correspondence is in Appendix C.

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Findings/Conclusion

The following findings seem to have been demonstrated during the course of the project work in either lecturing or consultation assistance or both:

1. To minimize the cost of combined effects or full slanting especially the addition of blast resistance to the accepted fallout protection, design professionals must think along those lines from the very first stage, and must be educating the policymakers to do the same, with help from DCPA/RESG staff professional engineers and architects.

2. The value of the two special P.C. courses offered was clearly shown by subsequent events.

3. There is apparently a need for technical guidance on the engineered, as well as expedient, blast upgrading of existing structures.

4. If combined effects protection is to be moved forward, then more of the kind of simplification/predesign work represented herein and in References 5 and 6 and their like must be done.

It is wholly unreasonable to expect engineers whose work is supervising A&E and construction contracts, to be structural engineers and expert in handling dynamic loadings and other nuclear weapons effects. They should have specialized help available whenever needed. Costs are small and savings are potentially significant in amount and professional time.

1. Murphy, H. L., Feasibility Study of Slanting for Combined Nuclear Weapons Effects (Revised), Stanford Research Institute Technical Report, for U.S. Office of Civil Defense (now Defense Civil Preparedness Agency), 2 vols., July 1971. (AD-734 831 and 2)
2. Murphy, H. L., and J. E. Beck, Slanting for Combined Nuclear Weapons Effects: EXAMPLES WITH ESTIMATES, AND AIR BLAST ROOM FILLING, (ibid.), June 1973. (AD-783 061)
3. Murphy, H. L., and J. R. Rempel, Slanting for Combined Nuclear Weapons Effects: FIRE HAZARD REDUCTION, (ibid.), August 1972. (AD-763 472)
4. Murphy, H. L., and J. E. Beck, Slanting for Combined Nuclear Weapons Effects: BLAST-RESISTANT DESIGN/ANALYSIS WITH EXAMPLES, (ibid.), December 1974. (AD-A016 631)
5. Murphy, H. L., J. R. Rempel, and J. E. Beck, SLANTING IN NEW BASEMENTS FOR COMBINED NUCLEAR WEAPONS EFFECTS: A Consolidated Printing of Four Technical Reports, (ibid.), 3 vols., October 1975. (AD-A023 237) Reports used are References 1, 2, 3 and 4 above.
6. Murphy, H. L., C. K. Wiehle, and E. E. Pickering, Upgrading Basements for Combined Nuclear Weapons Effects: Expedient Options, (ibid.), May 1976. (AD-A030 762)

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1. Murphy, H. L., Feasibility Study of Slanting for Combined Nuclear Weapons Effects (Revised), Stanford Research Institute Technical Report, for U.S. Office of Civil Defense (now Defense Civil Preparedness Agency), 2 vols., July 1971. (AD-734 831 and 2)
2. Murphy, H. L., and J. E. Beck, Slanting for Combined Nuclear Weapons Effects: EXAMPLES WITH ESTIMATES, AND AIR BLAST ROOM FILLING, (ibid.), June 1973. (AD-783 061)
3. Murphy, H. L., and J. R. Rempel, Slanting for Combined Nuclear Weapons Effects: FIRE HAZARD REDUCTION, (ibid.), August 1972. (AD-763 472)
4. Murphy, H. L., and J. E. Beck, Slanting for Combined Nuclear Weapons Effects: BLAST-RESISTANT DESIGN/ANALYSIS WITH EXAMPLES, (ibid.), December 1974. (AD-A016 631)
5. Murphy, H. L., J. R. Rempel, and J. E. Beck, SLANTING IN NEW BASEMENTS FOR COMBINED NUCLEAR WEAPONS EFFECTS: A Consolidated Printing of Four Technical Reports, (ibid.), 3 vols., October 1975. (AD-A023 237) Reports used are References 1, 2, 3 and 4 above.
6. Murphy, H. L., C. K. Wiehle, and E. E. Pickering, Upgrading Basements for Combined Nuclear Weapons Effects: Expedient Options, (ibid.), May 1976. (AD-A030 762)

Findings/Conclusion

The following findings seem to have been demonstrated during the course of the project work in either lecturing or consultation assistance or both:

1. To minimize the cost of combined effects or full slanting especially the addition of blast resistance to the accepted fallout protection, design professionals must think along those lines from the very first stage, and must be educating the policymakers to do the same, with help from DCPA/RESG staff professional engineers and architects.

2. The value of the two special P.C. courses offered was clearly shown by subsequent events.

3. There is apparently a need for technical guidance on the engineered, as well as expedient, blast upgrading of existing structures.

4. If combined effects protection is to be moved forward, then more of the kind of simplification/predesign work represented herein and in References 5 and 6 and their like must be done.

It is wholly unreasonable to expect engineers whose work is supervising A&E and construction contracts, to be structural engineers and expert in handling dynamic loadings and other nuclear weapons effects. They should have specialized help available whenever needed. Costs are small and savings are potentially significant in amount and professional time.

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